
FINAL REPORT

VOLUME 1 of 2 - SAMPLING/

RESULTS/SPECIAL TOPICS

**A Study of Toxic Emissions
from a Coal-Fired Power
Plant Utilizing the SNOX
Innovative Clean Coal
Technology Demonstration**

Contract DE-AC22-93PC93251

To

U.S. Department of Energy

Pittsburgh Energy Technology Center

July 1994

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on

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POWER PLANT UTILIZING THE SNOX INNOVATIVE
CLEAN COAL TECHNOLOGY DEMONSTRATION**

Contract DE-AC22-93PC93251

Prepared for

**U.S. DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER**

by

**BATTELLE
Columbus Operations
505 King Avenue
Columbus, Ohio 43201**

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EXECUTIVE SUMMARY

This document is the Final Report on the project titled "A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing the SNOX Innovative Clean Coal Technology Demonstration". This study was conducted for the U.S. Department of Energy, Pittsburgh Energy Technology Center (DOE-PETC), under Contract DE-AC22-93PC93251. The present study was one of a group of assessments of toxic emissions from coal-fired power plants, conducted for DOE during 1993. The motivation for those assessments was the mandate in the 1990 Clean Air Act Amendments that a study be made of emissions of hazardous air pollutants (HAPs) from electric utilities. The results of this study will be used by the U.S. Environmental Protection Agency to evaluate whether or not regulation of emissions of HAPs from electric utilities is warranted.

The report is organized in two volumes. Volume 1: Sampling describes the sampling effort conducted as the basis for this study; Results presents the concentration data on HAPs in the several power plant streams, and reports the results of evaluations and calculations conducted with those data; and Special Topics report on issues such as comparison of sampling methods and vapor/solid distributions of HAPs. Volume 2: Appendices include quality assurance/quality control results, uncertainty analysis for emission factors, and data sheets.

This study involved measurements of a variety of substances in solid, liquid, and gaseous samples from input, output, and process streams at the Innovative Clean Coal Technology Demonstration (ICCT) of the Wet Sulfuric Acid-Selective Catalytic Reduction (SNOX) process. The SNOX demonstration is being conducted at Ohio Edison's Niles Boiler No. 2 which uses cyclone burners to burn bituminous coal. A 35 megawatt slipstream of flue gas from the boiler is used to demonstrate SNOX. Measurements were made at the SNOX process on July 18-24, 1993. Cosponsors of the SNOX demonstration are the U.S. Department of Energy; ABB Combustion Engineering; Snamprogetti, USA; Ohio Edison; and the Ohio Coal Development Office.

The substances measured at the SNOX process were the following:

1. Five major and 16 trace elements, including mercury, chromium, cadmium, lead, selenium, arsenic, beryllium, and nickel
2. Acids and corresponding anions (HCl, HF, chloride, fluoride, phosphate, sulfate)
3. Ammonia and cyanide
4. Elemental carbon
5. Radionuclides

6. Volatile organic compounds (VOC)
7. Semi-volatile compounds (SVOC) including polynuclear aromatic hydrocarbons (PAH)
8. Aldehydes.

Some or all of these constituents were measured in solid, liquid, and gaseous input and output streams of the SNOX process, and in flue gas at key points within the SNOX process. In addition, particle size distributions were determined for flue gas particulate matter and for collected solid samples such as ash collected by the SNOX baghouse.

The measurement data from this study were used to address several objectives:

1. To assess the emission levels of selected HAPs
2. To determine for selected HAPs (a) the removal efficiencies of the SNOX process units, (b) material balances in individual components of the SNOX process, and (c) material balances for the SNOX process as a whole
3. To determine the particle size distribution of selected HAPs in the flue gas particulate matter
4. To determine the vapor/solid phase distribution of selected HAPs in flue gas streams.

These objectives were addressed by comparisons and calculations using the HAPs concentration data obtained during the field measurements, along with plant characteristics and operating conditions provided by Ohio Edison and ABB. The main results of this study in each of these areas are summarized below.

Emission Factors

The emission levels of the measured HAPs were calculated based on the concentrations measured in the flue gas leaving the SNOX process. Not unexpectedly, emission rates differed widely among the various types of HAPs. The emission rates are summarized in Tables ES-1 through ES-7. The average emission factor for each substance is shown along with an estimated uncertainty. For those substances whose concentrations were less than their detection limits for one or two of the three measurements, emission factors were calculated using a value of one-half the detection limit. When all three measurements of a substance were less than the detection limit, the average emission factor was determined using the full limits of detection. The data on emission factors present a comprehensive measurement of emissions from the SNOX process.

The average value of the emission factors for several of the trace elements was in the range 0.5 to 3 lb/10¹² Btu. The estimated uncertainty range varies from about 20 to 300 percent of the average values and is comprised principally of uncertainty due to error in precision. The average reported emission factor for mercury is 22 ± 13 lb/10¹² Btu.

Reported average emission factors for the major elements aluminum, potassium, and sodium exhibit considerable scatter and therefore estimated uncertainty.

Average emission factors for solid phase anions range from 2 lb/10¹² Btu for phosphate to 57,000 lb/10¹² Btu for sulfate. The sulfate emission may reflect sulfuric acid mist leaving the condenser in the SNOX system. Chloride and fluoride are reported as 25 and 157 lb/10¹² Btu, respectively. The emission factors for solid phase anions in flue gas were determined from single point sampling in the duct, not traversing.

Gas phase substances ammonia, cyanide, hydrogen chloride, and hydrogen fluoride have reported average emission factors of 56, 157, 82,400, and 6,630 lb/10¹² Btu. The contribution of bias to the estimated total uncertainty for these emission factors is 4, 20, 22, and 35 percent, respectively.

The reported average emission factors for radionuclide activity generally reflect non-detected values. The upper limit of these emission factors range from a low of 8.3 mCi/10¹² Btu for Pb²¹² to 2,130 mCi/10¹² Btu for U²³⁴.

For most volatile organic compounds, the reported average emission factors range from about 3.4 to 9.6 lb/10¹² Btu with most values reported as 5.8 lb/10¹² Btu based upon non-detected compounds. Emission factors for the four aldehydes range from 8.3 to 388 lb/10¹² Btu. Emission factors for the semivolatile organic compounds range from about 0.0005 to 0.3 lb/10¹² Btu.

Removal Efficiencies and Material Balances

Removal efficiencies and material balances were calculated for the major and trace elements. The removal efficiencies were determined to provide data on the efficacy of flue gas cleanup systems for controlling emissions of HAPs. Material balances were calculated to assess the consistency of the concentration data that were measured in various process streams.

Removal efficiencies for these elements were calculated for the SNOX baghouse and for the entire SNOX process. Removal efficiencies for most elements exceeded 99 percent in both cases. Results are shown in Table ES-8.

Material balances calculated across the baghouse and the entire SNOX process were within ± 50 percent of balance for most elements. The material balance on mercury was 106 percent for the SNOX baghouse and 118 percent for the entire SNOX system. However, some elements exhibited very low or very high material balances. Results are shown in Table ES-9.

Particle Size Distribution of HAPs

Particle samples were collected at one location in the SNOX process to document the dependence of elemental concentration upon particle size. The collection of size-segregated particle samples at the inlet to the SNOX baghouse suffered from the necessity of using an extractive approach to sampling. The cyclone collectors could not be inserted directly into the flue gas; a sampling probe and sampling line delivered sampled flue gas to the particle collectors. Unfortunately, over one-half of the fly ash by mass deposited onto the walls of the probe and sampling line before the sample reached the particle collectors. The data on size dependence of elemental composition are therefore of limited value. The results are qualitatively consistent with the expectation that the more volatile elements would be concentrated in the smaller size fly ash particles. The elements selenium, arsenic and antimony exhibit this trend and are in sharp contrast to aluminum, which was concentrated in the larger particle size fractions. The elements chromium, molybdenum, and sodium exhibit a more moderate trend of increased concentration in the smallest particle size fraction. Copper shows this trend to a lesser extent. The elements beryllium, cobalt, lead, manganese, nickel, potassium, and titanium are evenly distributed in the collected fly ash across the different size fractions.

Vapor/Solid Phase Distribution of HAPs

The vapor/solid phase distributions of elements and PAH/SVOC were determined. That evaluation shows that most of the elements measured exist entirely in the particle phase under all flue gas conditions encountered at SNOX. However, some elements, such as selenium, antimony, arsenic, lead, sodium, potassium, manganese, and boron, were found to be distributed between the vapor and particle phase, in proportions that depend on the flue gas particulate loading and temperature. At the outlet of the SNOX process, nearly all elements were found exclusively in the particle phase. Mercury alone was found almost entirely in the vapor phase at all flue gas locations where it was measured. The low concentrations of elements in the flue gas after the SNOX baghouse contributed to variability in the results for both the vapor and solid element concentration data.

Most PAH and SVOC compounds were found almost exclusively in the vapor phase, consistent with their volatility and the flue gas temperatures. Benzo[a]pyrene and other PAHs having five or more aromatic rings in their molecular structure were found only in the particle phase. A few PAH and SVOC of intermediate characteristics were distributed between the vapor and particle phases, in proportions that differed in a realistic manner with flue gas temperature. Those that were detected were present predominantly in the vapor phase, consistent with their volatility. Thus the element and PAH/SVOC data appear to provide a coherent and credible picture of the phase distributions of these species in the flue gas.

A Hazardous Element Sampling Train (HEST) was used to collect samples for analysis of mercury, selenium and arsenic at each location that a Method 29 sampling train was used to collect samples for elements. The vapor phase mercury concentrations reported from the Method 29 samples are more representative of the in-situ conditions in the SNOX

process than are the vapor phase results reported from the HEST sampling. The HEST results are low because of reduced trapping efficiency of the primary carbon-impregnated filter believed to be caused by condensation of sulfuric acid and/or lack of temperature control within a temperature range. Work to define further the dynamic range of operation conditions for HEST sampling of mercury needs to be conducted. The HEST results for vapor phase selenium and arsenic were much higher than the Method 29 results. The differences in results may be due to the effect of temperature on partitioning of these two elements between the vapor and solid phases.

A comparison of two methods for measuring VOC was made. Volatile organic compounds were collected in Volatile Organic Sampling Trains (VOST) as the primary method and also in canisters as the alternate method. Three samples were collected on each day at each flue gas location. The VOC data, whether collected by VOST or canisters, in general show a variation on concentration from collection to collection of a factor of two or less. Data from the VOST and canister collection methods generally agree within a factor of four. However, there does not seem to be a consistent trend between data obtained from the two methods. Recommendations for further investigation of these two methods to collect and measure VOC concentrations in flue gas are provided in the following section on Recommendations.

TABLE ES-1. EMISSION FACTORS FOR ELEMENTS (lb/10¹² BTU)

Analyte	Emission Factor	Uncertainty
Aluminum	240 a	NC
Potassium	77 ##	257
Sodium	390 a	NC
Titanium	1.3 ##	3.2
Antimony	ND < 0.50 #	0.50
Arsenic	ND < 0.50 #	0.50
Barium	0.17 ##	0.59
Beryllium	0.17 ##	0.27
Boron	NA	NA
Cadmium	0.092 ##	0.16
Chromium	3.9 a	NC
Cobalt	ND < 0.22 a	NC
Copper	0.89	0.70
Lead	0.53 ##	1.2
Manganese	2.6	3.1
Mercury	22	13
Molybdenum	5.4	3.6
Nickel	2.2 a	NC
Selenium	0.67	0.80
Vanadium	ND < 0.11 #	0.11

Uncertainty = 95 % confidence limit.

NA = Not analyzed.

ND < = Analyte not detected.

NC = Not calculated.

= Average emission factor includes three non-detects out of three measurements.

= Average emission factor includes one or two non-detects out of three measurements.

a = Emission factor based on two sets of measurements due to outliers.

TABLE ES-2. EMISSION FACTORS FOR AMMONIA/CYANIDE (lb/10¹² BTU)

<u>Analyte</u>	<u>Emission Factor</u>	<u>Uncertainty</u>
Ammonia	56 ^a	NC
Cyanide	157	82

Uncertainty = 95 % confidence limit.

NC = Not calculated.

^a = Emission factor based on two sets of measurements due to outliers.

TABLE ES-3. EMISSION FACTORS FOR ANIONS (lb/10¹² BTU)

<u>Analyte</u>	<u>Emission Factor</u>	<u>Uncertainty</u>
Hydrogen Chloride	82400	41800
Hydrogen Fluoride	6630	2110
Chloride (Particulate) **	25 ##	82
Fluoride (Particulate) **	157	621
Phosphate (Particulate) **	2.0 ##	3.5
Sulfate (Particulate) **	56600	61700

Uncertainty = 95 % confidence limit.

** = Sampling for anions was conducted at a single point in the duct; traverses were not made.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE ES-4. EMISSION FACTORS FOR VOC (lb/10¹² BTU)

Analyte	Emission Factor		Uncertainty
Chloromethane		218	472
Bromomethane		9.6 ##	9.3
Vinyl Chloride	ND <	5.8 #	5.8
Chloroethane		3.4 ##	1.8
Methylene Chloride		NC	NC
Acetone		NC	NC
Carbon Disulfide		5.4 ##	5.0
1,1-Dichloroethene	ND <	5.8 #	5.8
1,1-Dichloroethane	ND <	5.8 #	5.8
trans-1,2-Dichloroethene	ND <	5.8 #	5.8
Chloroform	ND <	5.8 #	5.8
1,2-Dichloroethane	ND <	5.8 #	5.8
2-Butanone	ND <	8.3 #	8.3
1,1,1-Trichloroethane	ND <	5.8 #	5.8
Carbon Tetrachloride	ND <	5.8 #	5.8
Vinyl Acetate	ND <	5.8 #	5.8
Bromodichloromethane	ND <	5.8 #	5.8
1,2-Dichloropropane	ND <	5.8 #	5.8
cis-1,3-Dichloropropylene	ND <	5.8 #	5.8
Trichloroethene	ND <	5.8 #	5.8
Dibromochloromethane	ND <	5.8 #	5.8
1,1,2-Trichloroethane		4.9 ##	10
Benzene		5.6	4.5
trans-1,3-Dichloropropylene	ND <	5.8 #	5.8
2-Chloroethylvinylether	ND <	5.8 #	5.8
Bromoform	ND <	5.8 #	5.8
4-Methyl-2-Pentanone	ND <	5.8 #	5.8
2-Hexanone		19 ##	51
Tetrachloroethene	ND <	5.8 #	5.8
1,1,2,2-Tetrachloroethane	ND <	5.8 #	5.8
Toluene		3.9 ##	5.3
Chlorobenzene	ND <	5.8 #	5.8
Ethylbenzene	ND <	5.8 #	5.8
Styrene	ND <	5.8 #	5.8
Xylenes (Total)	ND <	5.8 #	5.8

Uncertainty = 95% confidence limit.

ND < = Analyte not detected.

NC = Not calculated.

= Average emission factor includes three non-detects out of three measurements.

= Average emission factor includes one or two non-detects out of three measurement

TABLE ES-5. EMISSION FACTORS FOR PAH/SVOC (lb/10¹² BTU)

Analyte		Emission Factor	Uncertainty
Benzylchloride		0.025 ##	0.097
Acetophenone		0.30	0.44
Hexachloroethane	ND <	0.0055 #	0.0055
Naphthalene		0.060	0.060
Hexachlorobutadiene	ND <	0.0055 #	0.0055
2-Chloroacetophenone	ND <	0.0055 #	0.0055
2-Methylnaphthalene		0.020	0.044
1-Methylnaphthalene		0.011	0.023
Hexachlorocyclopentadiene	ND <	0.0055 #	0.0055
Biphenyl		0.0060 ##	0.018
Acenaphthylene		0.0042	0.0077
2,6-Dinitrotoluene	ND <	0.0055 #	0.0055
Acenaphthene		0.0053	0.0078
Dibenzofuran		0.013	0.0095
2,4-Dinitrotoluene		0.0038 ##	0.00091
Fluorene		0.00060 ##	0.00079
Hexachlorobenzene	ND <	0.0055 #	0.0055
Pentachlorophenol		0.0032 ##	0.0031
Phenanthrene		0.024	0.028
Anthracene		0.0036	0.0050
Fluoranthene		0.0069	0.0068
Pyrene		0.0012 ##	0.0027
Benz(a)anthracene		0.0021	0.00058
Chrysene		0.0021 ##	0.0030
Benzo(b & k)fluoranthene		0.0039	0.0021
Benzo(e)pyrene		0.0011 ##	0.0015
Benzo(a)pyrene		0.00094 ##	0.00071
Indeno(1,2,3-c,d)pyrene		0.0010 ##	0.0010
Dibenz(a,h)anthracene		0.00071 ##	0.00036
Benzo(g,h,i)perylene		0.00093 ##	0.00068

Uncertainty = 95% confidence limit.

ND < = Analyte not detected.

= Average emission factor includes three non-detects out of three measurements.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE ES-6. EMISSION FACTORS FOR ALDEHYDES (lb/10¹² BTU)

<u>Analyte</u>	<u>Emission Factor</u>	<u>Uncertainty</u>
Formaldehyde	57	24
Acetaldehyde	388	127
Acrolein	8.3	3.4
Propionaldehyde	13	21

Uncertainty = 95 % confidence limit.

TABLE ES-7. EMISSION FACTORS FOR RADIONUCLIDES (lb/10¹² BTU)

<u>Analyte</u>	<u>Emission Factor</u>	<u>Uncertainty</u>
Pb-212	ND < 8.3 #	8.3
Th-234	47 ##	43
Pb-210	ND < 94 #	94
Pb-211	ND < 119 #	119
Ra-226	ND < 12 #	12
Ra-228	ND < 27 #	27
Th-229	ND < 50 #	50
Th-230	ND < 540 #	540
U-234	ND < 2130 #	2130
U-235	ND < 75 #	75

Uncertainty = 95 % confidence limit.

ND < = Analyte not detected.

= Average emission factor includes three non-detects out of three measurements.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE ES-8. REMOVAL EFFICIENCIES FOR THE SNOX
BAGHOUSE AND ENTIRE SNOX SYSTEM

Element	Removal Efficiency (Percent)	
	Baghouse	SNOX System
Aluminum	99.54	99.77#
Potassium	99.02	99.73
Sodium	80*	89.15#
Titanium	99.97	99.99#
Antimony	99.74#	99.61#
Arsenic	99.61	99.99#
Barium	99.87	99.98#
Beryllium	99.93#	99.69#
Boron	NA	NA
Cadmium	99.04#	97.90#
Chromium	99.32*	99.09*
Cobalt	99.96	99.93#
Copper	99.81	99.86
Lead	99.95#	99.91#
Manganese	99.45	99.34
Mercury	(5)	(13)
Molybdenum	99.04	96.92
Nickel	99.95#*	99.56*
Selenium	17	99.12
Vanadium	100#	99.99#

At least one non-detect value was used in calculating the result.

* A value substituted for an outlier was used in calculating the daily removal efficiencies.

TABLE ES-9. MATERIAL BALANCES FOR THE SNOX
BAGHOUSE AND ENTIRE SNOX SYSTEM

Element	Material Balance (Percent)	
	Baghouse	SNOX System
Aluminum	142	142#
Potassium	129	129#
Sodium	303	283#
Titanium	110	110
Antimony	110#	111#
Arsenic	80	80#
Barium	146	147#
Beryllium	110#	111#
Boron	NA	NA
Cadmium	52	62#
Chromium	101*	102*
Cobalt	96	97#
Copper	112	112
Lead	143#	143#
Manganese	102	102
Mercury	106	118
Molybdenum	103	108
Nickel	101#	101*
Selenium	100	287
Vanadium	106#	106#

At least one non-detect value was used in calculating the result.

* A value substituted for an outlier was used in calculating the daily removal efficiencies.

RECOMMENDATIONS

The experience gained in studying emissions of hazardous air pollutants (HAPs) from the SNOX process led to the following recommendations for future studies at power plants utilizing an advanced flue gas cleanup system:

SAMPLING

1. Number of Sample Sets to Collect

Battelle recommends that four sets of samples be collected for a study of HAPs. If measurements from one of the four samples cannot be used or yield results that cannot be explained, three samples remain to form the average and estimate of variability.

2. Quality Assurance Samples

Battelle recommends that a minimum of one field sampling train blanks be processed at each flue gas sampling site for each group of 3-4 sample sets that are collected.

3. Hazardous Element Sampling Train

The range of flue gas conditions under which the Hazardous Element Sampling Train (HEST) can be used effectively needs further investigation. In particular the influence of acid and temperature on HEST sampling needs to be documented.

Application of denuder techniques to remove vapor species from the flue gas prior to collecting particles should be investigated to improve methods to determine partitioning of selected species between the vapor and solid phases.

4. Collection of Volatile Organic Compounds

- a. Battelle recommends that an investigation be made of the variability in results of measurements by both the canister method of collecting and analyzing volatile organic compounds (VOC) and the volatile organic sampling train (VOST) method. The use of internal standards spiked on the Tenax adsorbent or into the evacuated canister prior to sampling would aid in determining if reactions are occurring with the VOCs following sample collection. Battelle recommends that a continuous (or near continuous) instrument for monitoring one or more of the VOCs be used to assess fluctuation of VOC concentrations in flue gas. For example, a gas chromatograph equipped with a photo-ionization detector or mass selective detector could provide information on one or two VOC in less than 30 minutes from the end of sample collection.

- b. Dichloromethane, used as a solvent for other sampling, was found in both the VOST and canister sampling trains. Battelle recommends that VOC sampling apparatus be kept away from dichloromethane if this compound is to be measured. The need for measuring dichloromethane must be balanced against the cost and extra effort to ensure that the VOC samples are not contaminated by the solvent dichloromethane in the field.

5. Use of Out-of-Duct Cyclones

If size-segregated fly ash is to be collected ahead of control equipment for particulate matter, and if available sampling ports or duct configuration at that location do not permit cyclones to be inserted into the duct, Battelle recommends that size-segregated sampling not be conducted. The deposition of particles in sampling lines leading to out-of-duct cyclones may make the material collected in the cyclones not representative of the particle size distribution in the duct.

6. Sampling the Outlet of a Selective Catalytic Reduction (SCR) Reactor

If sampling is to be conducted following a SCR reactor, the temperature of the flue gas may be between 200 and 300 °C, and ammonia slip and sulfur compounds are likely to be present in the flue gas. Under such conditions, sampling must be conducted at a temperature in excess of that at which the ammonia and sulfur compounds will react to produce solid ammonium bisulfate and ammonium sulfate.

7. Sampling the Outlet of a Wet Sulfuric Acid (WSA) Condenser Tower

In sampling of the outlet of a WSA condenser tower, as at the SNOX, condensation of sulfuric acid mist may lead to erroneous measurements of flue gas particulate loading. Under such conditions, sampling should be conducted at a temperature in excess of that at which sulfuric acid mist can condense.

8. Sampling at the Niles SNOX Selective Catalytic Reduction (SCR) Reactor

Should future sampling be required at the Niles SNOX SCR reactor, the sampling parts should be modified prior to sampling. Temporary modifications were made in this study to allow adequate sampling across most of the duct at the SCR outlet. Permanent replacement of all of the narrow-bore ports on the SCR reactor is recommended.

9. Minimizing Background Contamination in Method 29 Sampling

Stringent procedures should be followed to avoid potential field and reagent contamination of Method 29 samples. Before the Method 29 train is assembled in the field, all glassware and associated surfaces expected to come into contact with flue gas should be rinsed multiple times with nitric acid and distilled water as described in Method 29. If HPLC grade distilled deionized water is not available at the test site,

adequate quantities should be brought from the laboratory. All target elements should be less than 1 ng/mL in the water. If the train components cannot be immediately assembled, then they should be covered with a clean and dry sheet of plastic (Saran Wrap or equivalent) or with an overturned cleaned plastic tub of adequate size until they are ready to be used. Clean closefitting gloves of a material compatible with acids should be used while assembling and disassembling the trains.

Sampling reagents must be suitable for trace level element work. The sample filters should not have organic binders and should consist of high purity quartz containing less than $1.3 \mu\text{g}/\text{in.}^2$ of each of the elements to be measured. Analytical results provided by the filter manufacturer stating elements contents of the filter is acceptable. Stock nitric acid, hydrochloric acid, acetone, and potassium permanganate should be suitable for trace element analysis. For acids, Baker Instra-Analyzed™ or Fisher OPTIMA™ brands are recommended. The acidified peroxide and potassium permanganate impinger solutions should contain less than 2 ng/mL of the target element. Glassware used to prepare the reagents should also be cleaned in the same manner as the train components. Sample bottles to be used for containing the various solutions from the train should be opened just prior to filling and capped immediately thereafter. Commercial sample bottles for trace element work are available, or should be rinsed with acid and water in preparation for the field test.

ANALYSIS OF SAMPLES

1. Digestion of Samples for Elemental Analysis

For better quantification of major and trace elements in a single sample, separate aliquots of the sample should be digested for analysis if possible. Separate digestions will allow dilutions typically necessary for accurate determination of major elements without affecting detection of trace elements.

2. Boron Determinations

The use of HF-resistant instrumentation for element analysis should be mandatory. This type of instrumentation will eliminate the need to complex HF-digested samples with boric acid which prevented the determination of boron in some of the analyses on this program.

3. Phase Partitioning of PAH/SVOC

When sufficient data have been obtained by DOE on the vapor/particulate distribution of semivolatile organic compounds (PAH/SVOC) in coal-fired emissions, Battelle recommends that in subsequent work, vapor and solid phase samples of PAH/SVOC from flue gas should be prepared and analyzed as a single sample to improve detection limits.

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LIST OF ABBREVIATIONS AND ACRONYMS

μg	microgram, i.e., 1×10^{-6} gram
μl or μL	microliter, i.e., 1×10^{-6} liter
μm	micrometer, i.e., 1×10^{-6} meter
ALD	aldehydes
ASTM	American Society for Testing and Materials, and techniques specified by that organization
BAGH	baghouse
BCO	Battelle Columbus Operations
Btu	British thermal unit
C or $^{\circ}\text{C}$	degrees Centigrade
C6	hexane
CAAA	1990 Clean Air Act Amendments
CN	cyanide
CTE	Commercial Testing and Engineering Company
CTE-Denver	Commercial Testing and Engineering Company, Denver, CO, Laboratory
CV-AAS	cold vapor atomic absorption spectrometry
D_{50}	particle size for which the collection efficiency of a device or stage is 50 percent
DCM	dichloromethane (i.e., methylene chloride)
DL Ratio	detection limit ratio, indicates the portion of a result that is contributed by non-detect values
DNPH	2,4-Dinitrophenylhydrazine, reagent used for aldehyde sampling

DOE-PETC	Department of Energy, Pittsburgh Energy Technology Center
dscm	dry standard cubic meter (standard conditions are 68°F and 29.92 in. Hg)
EA	Element Analysis Corporation
E	emission factor
EPA	U.S. Environmental Protection Agency
ESP	electrostatic precipitator
F or °F	degrees Fahrenheit
F	filter
g	gram
GC/HRMS	gas chromatography/high resolution mass spectrometry
GC/MS	gas chromatography/mass spectrometry
GF-AAS	graphite furnace atomic absorption spectrometry
HAPs	hazardous air pollutants
HEST	Hazardous Element Sampling Train
HPLC/UV	high performance liquid chromatography with ultraviolet absorption detection
hr	hour
IC	ion chromatography
ICCT	Innovative Clean Coal Technology
ICP/AES	inductively coupled plasma atomic emission spectrometry
ID	identification (of a sample)
in. Hg	inches of mercury (Hg); unit of pressure, one inch of mercury equals 0.4898 pound per square inch

ISE	ion selective electrode
IT	International Technology Corporation
K	degrees Kelvin, i.e., absolute temperature
kg	kilogram, i.e., 1×10^3 g ($1 \text{ kg} = 2.20 \text{ lb}$)
klb	kilo-pounds, i.e., 1×10^3 pounds
kPa	kilo Pascals, i.e., 1×10^3 Pascals; a unit of pressure ($6,892.9 \text{ Pascals} = 1 \text{ pound per square inch}$)
L	liter
lb	pound
mCi	milli-Curie, i.e., 1×10^{-3} Curie (one Curie equals 3.7×10^{10} radioactive disintegrations per second)
MEOH	methanol
MFR	mass flow rate
mg	milligram, i.e., 1×10^{-3} gram
min	minute
MJ	mega Joules, i.e., 1×10^6 Joules ($1055 \text{ Joules equal one Btu}$)
ml or mL	milliliter, i.e., 1×10^{-3} liter
MM5	Modified Method 5
MUM	Multi-Metals Train (EPA Method 29)
MW	megawatts
NA	data not available, sample not available, or sample not analyzed
NC	not calculated
Ncm	<i>normal cubic meter (standard conditions are 0°C and 29.92 in. Hg). Except as indicated, all values in Ncm are also normalized to dry conditions and three percent oxygen content of the flue gas.</i>

ND	not detected (generally accompanied by indication of the detection limit, e.g., ND < 4.0)
NDIR	non-dispersive infrared
ng	nanogram, i.e., 1×10^{-9} gram
Nm ³ or Nm ^{^3}	See Ncm
NO _x	oxides of nitrogen (nitric oxide, NO, and nitrogen dioxide, NO ₂)
PAH	polynuclear aromatic hydrocarbons
pCi	pico-Curie, i.e., 1×10^{-12} Curie (one Curie equals 3.7×10^{10} radioactive disintegrations per second)
pg	picogram, i.e., 1×10^{-12} gram
PIXE	proton induced X-ray emission spectrometry
ppbv	part per billion by volume, i.e., 1×10^{-9} v/v, measure of gaseous concentration in air
ppm	part per million, i.e., 1×10^{-6} by volume (generally of a pollutant in air or stack gas)
PRL	Process sample (liquid)
PSDS	Plume Simulating Dilution Sampler
psi or psig	pounds per square inch (gauge); i.e., gauge pressure is relative to atmospheric pressure
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Program Plan
RAD	radionuclide analyses
RE	removal efficiency
RTI	Research Triangle Institute, quality assurance auditors for the project
s	second (of time)

scfm	standard cubic feet per minute
SCM, scm	standard cubic meters
SCR	selective catalytic reduction
SD	standard deviation
SNOX	acronym for Selective Catalytic Reduction of NO _x
SO ₂	sulfur dioxide
SVOC	semivolatile organic compounds
TU	total uncertainty
VOC	volatile organic compounds
VOS	sample collected with VOST
VOST	Volatile Organic Sampling Train
WSA	acronym for Wet Sulfuric Acid
X	XAD resin, for SVOC collection in Modified Method 5 train

1.0 INTRODUCTION

The Clean Air Act Amendments (CAAA) of 1990 direct that a study be made of emissions of hazardous air pollutants (HAPs) from electric utilities. Results of the study will be used by the United States Environmental Protection Agency (EPA) to evaluate whether or not regulation of emissions of HAPs from this industrial sector is warranted. If a finding is made that regulation is warranted for specific HAPs, rulemaking activities will proceed. In addition, control strategies must be developed for those HAPs that are to be regulated.

This report presents information from a project that is a part of the study identified above. This project was conducted for the U.S. Department of Energy's Pittsburgh Energy Technology Center as one of a group of assessments of toxic emissions from coal-fired power plants. This project is a "Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing the SNOX Innovative Clean Coal Technology Demonstration Project". The host power plant for this project was Ohio Edison's Niles Station, in Niles, Ohio. Niles Boiler No. 2 is a cyclone boiler burning bituminous coal. The pollution control technology on a slipstream of flue gas from Boiler No. 2 that was tested is the Selective Catalytic Reduction of NO_x (SNOX) process.

1.1 Objectives

The objectives of this project for the SNOX process are:

- (1) To collect and analyze representative solid, liquid, and gas samples of input and output streams of the SNOX process, for selected HAPs that are listed in Title III of the 1990 Clean Air Act Amendments, and to assess the emission level of these pollutants.
- (2) To determine for selected HAPs (a) the removal efficiencies of pollution control subsystems of the SNOX process, (b) material balances in specified process streams, and (c) an overall material balance for the SNOX process.
- (3) To determine the concentration of selected HAPs associated with the particulate fraction of the flue gas stream as a function of particle size.

- (4) To determine the distribution of selected HAPs associated with the vapor and particulate phase fractions in the flue gas at various points downstream while assessing the emission levels of these pollutants.

1.1.1 Objectives of DOE and EPA

The U.S. DOE will use the results of this project in its Flue Gas Cleanup Program to provide technology options that will allow for existing and future coal use in a manner that respects the environment. Under this program, control systems are being developed for airborne emissions of HAPs from coal-fired power plants. Results of this project along with the other projects in the assessment of toxic emissions will provide a database on the efficacy of a variety of control systems for HAPs generated by combustion of a variety of coals.

The U.S. EPA will use the results of this project along with other data to help fulfill the mandate in the CAAA for the Utility Toxics Study. Data on emissions along with results on removal efficiencies will be used to assess whether or not regulation of HAPs is warranted for the electric utility industry.

1.1.2 Substances Measured

To meet the objectives of the project, measurements were made of the concentrations of a comprehensive set of substances. The analytes that were measured are listed in Tables 1-1 through 1-5.

Major and trace elements are listed in Table 1-1. The major elements were measured to provide additional parameters to be used in the material balance calculations. Because these elements exist at much higher concentrations in coal and fly ash than do the trace elements that are classified as HAPs, they are expected to have less uncertainty in their determination. Hence they can serve as benchmarks for the material balance calculations of trace elements. Five major elements were measured. Sixteen trace elements were measured. Three of the trace elements, As, Se, and Hg, are volatile and were measured in both the vapor and particle phases of flue gas streams.

Other inorganic substances that were measured include the anions chloride, fluoride, phosphate, and sulfate. These anions were measured in solid, liquid, and flue gas process streams. In addition, ammonia and cyanide were measured in flue gas streams. Elemental carbon was measured in flue gas streams and in baghouse ash. The ten radionuclides listed in Table 1-1 were also measured.

Organic substances that were measured include semi-volatile organic compounds (SVOC), volatile organic compounds (VOC), and aldehydes. Semi-volatile organic compounds include polycyclic aromatic hydrocarbons (PAH), and other SVOC. Table 1-2 lists PAH and other SVOC that were measured in flue gas and solid process streams. These compounds were measured in both the vapor and particle phases of the flue gas streams.

Volatile organic compounds were measured in flue gas streams. Table 1-3 contains a list of VOC that were measured in flue gas streams using a volatile organic sampling train (VOST). Canisters were used to collect VOC from flue gas streams as an alternative collection method for comparison. The compounds measured in canister samples are listed in Table 1-4.

Measurements were made of four aldehydes in flue gas and liquid process streams. These compounds are listed in Table 1-5.

1.1.3 Target Detection Limits

Target detection limits for the substances cited in Section 1.1.2 were developed based upon the intended use of the data by the DOE and EPA subject to resource and schedule constraints of the project. Target detection limits account for the planned volume of sample to be collected and the analytical detection limit for an analyte in a given quantity of sample. The target detection limits for the project are listed in Tables 1-6 and 1-7. For some of the analytes listed in Table 1-6, the analytical method is noted. The right hand column in Table 1-6 gives the target detection limits in nanograms for each analyte in a sample. Using this information, the target detection limits for substances in flue gas samples is shown in Table 1-7. Target detection limits were not developed for major elements because these elements were present in all samples at levels far above their detection limits.

The greatest challenge in meeting the target detection limits for flue gas streams was collecting sufficient material from the flue gas streams at the exit of control equipment. This in turn depended principally upon the quantity of flue gas that was collected in these process streams. The sampling rate and duration of sampling were selected to meet the target detection limits shown in Table 1-7.

1.1.4 Particle Size Range

The need for the Utility Toxics Study mandated in the CAAA is driven by concern over the impact of emissions on public health. To collect data with the most relevance to issues of public health, samples of size-segregated particulate matter in the range of particle diameters that are inhaled into the respiratory system were collected from flue gas. Particulate matter collected for analysis for metals and for SVOC was collected in the particle diameter range less than 10 μm . At selected locations glass cyclone collectors with 50 percent particle diameter cut points of 10 μm and 5 μm preceded a filter in the sampling train. Particles were collected in three size ranges at these locations.

In addition, at selected flue gas locations cascade impactors were used to measure the size distribution of particle mass. Particle mass was collected in eight size ranges below about 10 μm .

1.2 Scope of Project

Three sets of measurements were made on the substances identified in Section 1.1.2. Each set of measurements was conducted over a two-day period. Each two-day period consisted of one day devoted to collecting samples for organic analysis followed by a day devoted to inorganic substances.

In addition to measuring the concentration of substances in process streams, several special topics were investigated. These include the following:

- Measuring the distribution of elements and SVOC in the vapor and particle phases

- Measuring the concentration of elements in three particle size ranges
- Measuring mercury using a hazardous element sampling train (HEST) for comparison to U.S. EPA Method 29 measurements
- Collecting VOC in canisters to compare results with samples collected with a volatile organic sampling train (VOST).

1.3 Quality Assurance Audits

A quality assurance program was implemented to evaluate adherence to planned sampling and analytical procedures in the project Quality Assurance Project Plan (QAPP).^{*} The QAPP contained site-specific quality assurance/quality control (QA/QC), sampling and analytical plans. Internal audits conducted by Battelle were supplemented by external audits conducted by Research Triangle Institute (RTI) under contract to the U.S. EPA.

1.3.1 Internal Audits

Battelle conducted an internal QA/QC program for the project that was described in the QAPP. Internal QA/QC was the direct responsibility of the field sampling team and laboratory personnel at all levels. Battelle assigned a QA project officer to the project. She conducted both field and laboratory audits to document Battelle's adherence to the QAPP.

1.3.2 External Audits

The external QA program included a review of the QAPP for the project by RTI and both performance evaluation audits and technical systems audits at the power plant. Performance evaluation audits consisted of RTI challenging monitors with calibration gases and spiking impinger solutions and filters with analytes. Technical systems audits consisted

^{*}Final Niles QA/QC, Sampling, and Analytical Plans, July 17, 1993. Prepared by Battelle under Contract No. DE-AC22-93PC93251.

of RTI observing the procedures for sampling and handling samples to evaluate adherence to procedures in the QAPP.

1.4 Project Organization

Several organizations contributed to the project. An organization chart is shown in Figure 1-1. Battelle was the prime contractor and reported to DOE. Battelle worked directly with the host utility, Ohio Edison, through a Host Site Agreement.

The external QA program was conducted by RTI under contract to the U.S. EPA. The DOE and EPA coordinated the external audit activities.

A round robin program for coal analysis was coordinated by Consol, Inc. under contract to DOE. For this program, coal samples from eight power plants and a quality control sample were sent to Battelle and the other prime contractors in DOE's program. Results of Battelle's analysis will be presented in the Final Report.

Battelle had a major subcontractor, Chester Environmental, for sampling and some analyses. Chester conducted hot flue gas sampling at selected locations. Chester analyzed HEST samples for mercury, arsenic, and selenium and VOST samples for VOC. Zande Environmental Services analyzed liquid samples for VOC. Commercial Testing & Engineering Company (CTE) generated composite samples from solid process samples and analyzed gas, solid, and liquid samples for elements. International Technology Corporation provided radionuclide analyses. Element Analysis Corporation analyzed coal samples for elements as a quality assurance check on CTE's analysis by other methods.

The Energy and Environmental Research Center at the University of North Dakota reviewed the draft Final Report and provided comments to the DOE and Battelle.

1.5 Organization of the Report

This report describes the sampling conducted on the SNOX process at Ohio Edison's Niles Station and the results. Included in this volume of the report are descriptions of the plant and its operating conditions, sampling locations and schedules, problems encountered,

and solutions or modifications devised to address them. Occurrences or problems resulting in deviations from the sampling plan are noted.

The host utility site is described in Section 2. Operating parameters during the test are also summarized in Section 2.

In Section 3 the schedule for sampling is summarized along with information on the samples that were collected. Results for ash content of the process streams are presented. Oxygen content of the flue gas at several locations is presented to estimate the infiltration of air into the flue gas.

Section 4 of the report lists the analytical methods used to analyze samples. The analytical results are presented in Section 5. Section 6 provides analysis and interpretation of the data. This is presented in three ways: (1) material balance calculations for the plant and individual process components, (2) emission factors, and (3) calculated removal efficiencies for trace elements by control equipment.

Special topics that were investigated are summarized in Section 7. These topics are:

- Distribution of elements and PAH/SVOC between the vapor and particle phases
- Particle size distribution of elements in flue gas streams
- Comparison of measurements of mercury, arsenic, and selenium made by Method 29 sampling and sampling using a hazardous element sampling train (HEST)
- Comparison of measurements of VOC using VOST and canister methods.
- Mercury Results for Individual Method 29 Components

Volume 2 of the report contains appendices. These appendices provide additional information on sampling and analytical procedures, the quality assurance program, estimation of uncertainty in emission factors, and data sheets.

TABLE 1-1. INORGANIC SUBSTANCES MEASURED IN SOLID, LIQUID,
AND GAS PROCESS STREAMS

<u>Major Elements</u>	<u>Trace Elements</u>
Al, K, Ti, Si, Na	As, Se, Hg, Cd, Cr, Mo, B, Sb, Ba, Be, Pb, Mn, Ni, V, Cu, Co
<u>Anions</u>	<u>Other</u>
Cl ⁻ , F ⁻ , PO ₄ ⁼ , SO ₄ ⁼	NH ₃ , CN ⁻ , C
<u>Radionuclides</u>	
U ²³⁴ , U ²³⁵ , Th ²²⁹ , Th ²³⁰ , Th ²³⁴ , Ra ²²⁶ , Ra ²²⁸ , Pb ²¹⁰ , Pb ²¹¹ , Pb ²¹²	

TABLE 1-2. PAH AND OTHER SVOC MEASURED IN FLUE GAS
AND SOLID PROCESS STREAMS

<u>PAH</u>	<u>SVOC</u>
Naphthalene	Acetophenone
1-Methylnaphthalene	Benzyl chloride
2-Methylnaphthalene	2-Chloroacetophenone
Biphenyl	Dibenzofuran
Acenaphthene	2,4-Dinitrotoluene
Acenaphthylene	2,6-Dinitrotoluene
Phenanthrene	Hexachlorobenzene
Anthracene	Hexachlorobutadiene
Fluorene	Hexachlorocyclopentadiene
Fluoranthene	Hexachloroethane
Pyrene	Pentachlorophenol
Benz[a]anthracene	
Chrysene	
Benzo[e]pyrene	
Benzo[a]pyrene	
Benzo[b and k]fluoranthene	
Indeno[1,2,3-c,d]pyrene	
Benzo[g,h,i]perylene	
Dibenzo[a,h]anthracene	

TABLE 1-3. VOC COLLECTED BY VOST FROM
FLUE GAS PROCESS STREAMS

Chloromethane	Chloroform	Dibromochloromethane
Bromomethane	1,2-Dichloroethane	1,1,2-Trichloroethane
Vinyl chloride	2-Butanone	Benzene
Chloroethane	1,1,1-Trichloroethane	trans-1,3-Dichloropropene
Methylene chloride	Carbon tetrachloride	2-Chloroethylvinylether
Acetone	Vinyl acetate	Bromoform
Carbon disulfide	Bromodichloromethane	4-Methyl-2-pentanone
1,1-Dichloroethene	1,2-Dichloropropane	2-Hexanone
1,1-Dichloroethane	cis-1,3-Dichloropropene	Tetrachloroethene
trans-1,2-Dichloroethene	Trichloroethene	Toluene
1,1,2,2-Tetrachloroethane	Chlorobenzene	Ethylbenzene
Styrene	Xylenes (Total)	Hexane

**TABLE 1-4. VOC COLLECTED IN CANISTERS FROM
FLUE GAS PROCESS STREAMS**

Dichlorodifluoromethane (Freon-12)	trans-1,3-Dichloropropene
Methyl chloride	1,1,2-Trichloroethane
1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon-114)	Toluene
Vinyl chloride	1,2-Dibromoethane
Methyl bromide	Tetrachloroethene
Ethyl chloride	Chlorobenzene
Trichlorofluoromethane (Freon-11)	Ethylbenzene
1,1-Dichloroethene	m&p-Xylene
Dichloromethane	Styrene
3-Chloropropene	1,1,2,2-Tetrachloroethane
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113)	o-Xylene
1,1-Dichloroethane	4-Ethyltoluene
cis-1,2-Dichloroethene	1,3,5-Trimethylbenzene
Trichloromethane	1,2,4-Trimethylbenzene
1,2-Dichloroethane	Benzyl chloride
1,1,1-Trichloroethane	m-Dichlorobenzene
Benzene	p-Dichlorobenzene
Carbon tetrachloride	o-Dichlorobenzene
1,2-Dichloropropane	1,2,4-Trichlorobenzene
Trichloroethene	Hexachlorobutadiene
cis-1,3-Dichloropropene	

**TABLE 1-5. ALDEHYDES MEASURED IN
FLUE GAS PROCESS STREAMS**

Formaldehyde	Acrolein
Acetaldehyde	Propionaldehyde

TABLE 1-6. TARGET ANALYTICAL DETECTION LIMITS

Target Analyte	Estimated Instrument Detection Limit, ng/mL	Final Sample Volume, mL	Estimated Detection Limit, ng
Elements^(c)			
Mo (ICP-AES)	25 ^(a)	450, or 25 ^(b)	11250, or 625 ^(b)
B (ICP-AES)	20	450, or 25	9000, or 500
Sb (GF-AAS)	5	450, or 25	2250, or 75
As (GF-AAS)	1	450, or 25	450, or 25
Ba (ICP-AES)	5	450, or 25	2250, or 75
Be (ICP-AES)	5	450, or 25	2250, or 75
Cd (GF-AAS)	5	450, or 25	2250, or 75
Cr (ICP-AES)	20	450, or 25	9000, or 500
Pb (GF-AAS)	1	450, or 25	450, or 25
Mn (ICP-AES)	5	450, or 25	2250, or 75
Hg (CV-AAS)	0.5	450, or 25	225, or 12.5
Ni (ICP-AES)	20	450, or 25	9000, or 500
Se (GF-AAS)	2	450, or 25	900, or 50
V (ICP-AES)	10	450, or 25	4500, or 250
Cu (ICP-AES)	10	450, or 25	4500, or 250
Co (ICP-AES)	15	450, or 25	6750, or 375
Volatile Elements			
As	1.6 ng/cm ²		16
Se	1.9 ng/cm ²		19
Hg	2.5 ng/cm ²		25
Ammonia	500 ^(a)		225000
Cyanide	250 ^(a)		112500
Anions			
F ⁻	10 ^(a)		4500 or 100 ^(b)
Cl ⁻	10		4500 or 100
PO ₄ ³⁻	100		45000 or 1000
SO ₄ ²⁻	25		11250 or 250

TABLE 1-6. (Continued)

Target Analyte	Estimated Instrument Detection Limit, ng/mL	Final Sample Volume, mL	Estimated Detection Limit, ng
SVOC/PAH - Gas and Solid Samples	10-100	0.1-1	1-100
VOC - Canister		15	2 ppb
VOC-VOST			25
Aldehydes	6	20	120
Radionuclides	0.2 pCi/g		

- (a) Instrument detection limit is also equal to the detection limit in the liquid sample.
- (b) The first number applies to the gas sample, and the second number applies to the solid sample.
- (c) Acronym within parentheses refers to analysis method for elements: ICP-AES = inductively coupled plasma atomic emission spectrometry; GF-AAS = graphite furnace atomic absorption spectrometry; and CV-AAS = cold vapor atomic absorption spectrometry.

TABLE 1-7. TARGET GASEOUS EMISSION DETECTION LIMITS

	Analytical Detection Limit (ng)	Gas Volume Sampled (Nm ³)	Emission Detection Limit (µg/Nm ³)
Element			
Mo	11250	7.6	1.5
B	9000	7.6	1.2
Sb	2250	7.6	0.3
As	450	7.6	0.06
Ba	2250	7.6	0.3
Be	2250	7.6	0.3
Cd	2250	7.6	0.3
Cr	9000	7.6	1.2
Pb	450	7.6	0.06
Mn	2250	7.6	0.3
Hg	225	7.6	0.03
Ni	9000	7.6	1.2
Se	900	7.6	0.12
V	4500	7.6	0.6
Cu	4500	7.6	0.6
Co	6750	7.6	0.9
Ammonia	225000	0.3	750
Cyanide	112500	0.59	191
Anions			
F ⁻	4500	1.5	3
Cl ⁻	4500	1.5	3
PO ₄ ⁼	45000	1.5	30
SO ₄ ⁻	11250	1.5	7.5
SVOC ^(a)	1-100	7.6	0.0001-0.01
Aldehydes	120	0.06	2
VOC - Canister	2 ppb	NA ^(b)	6
VOC - VOST	25	0.003-0.018	1.3-7.5

(a) Calculated target emission detection limit will range from 0.1 to 10 ng/Nm³ depending upon SVOC compound and matrix.

(b) NA = Not applicable.

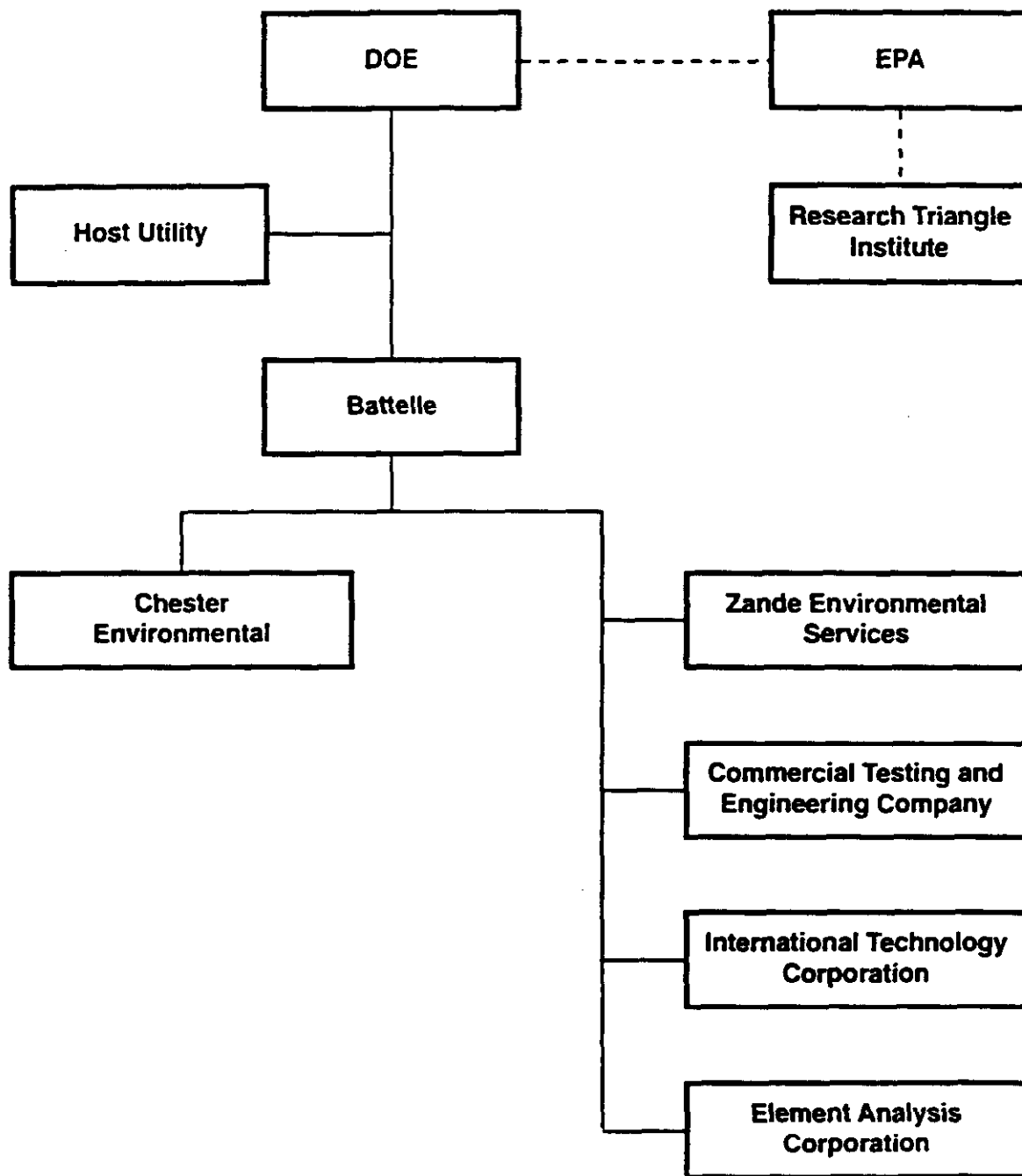


Figure 1-1. Project organization

2.0 SITE DESCRIPTION

The host site for this study was the Innovative Clean Coal Technology (ICCT) SNOX demonstration at Ohio Edison's Niles Station Boiler No. 2. The site is described in this section of the report as follows. The configuration of the boiler and SNOX process is described followed by a description of the process streams locations at which samples were collected. Finally, the expected and actual operating conditions of the boiler and SNOX process during the study are summarized.

2.1 Plant Configuration

The configuration of the power plant unit and the SNOX process is summarized in this section. During the period of sampling for this project, a few operating procedures for the power plant unit and the SNOX process were modified. These modifications are noted.

2.1.1 Boiler No. 2

Niles Station of Ohio Edison is located in Niles, Ohio, on the bank of the Mahoning River. The Niles Boiler No. 2 is a Babcock & Wilcox cyclone boiler burning bituminous coal with a net generating capacity of 100 megawatts. The boiler has four cyclone burners, each fed by a separate feeder. Nominal sulfur content of the coal is 2.8 percent. The coal comes from several local sources and is blended in the coal yard to meet 24-hour and 30-day rolling averages for SO₂ content of flue gas.

The flue gas leaves the boiler, passes through an air heater, and enters an electrostatic precipitator (ESP) with five fields, each with two hoppers. The flue gas leaving the ESP is vented through a 120-m (393-foot) tall stack.

The SNOX process takes a slipstream of flue gas ahead of the ESP, cleans the slipstream, and returns the slipstream to the flue gas after the ESP and before the stack. This is shown in Figure 2-1. All flue gas sampling was conducted on the slipstream of the SNOX process. Therefore operation of the ESP had no effect on the measurements summarized in this report.

Normally, soot blowing occurs once each shift. Ohio Edison altered the schedule for soot blowing during the field study. Soot blowing was conducted a couple hours before sampling began each day and again after sampling was completed each day.

Ammonia is normally added to the flue gas before the ESP at a rate of 0.1-0.2 m³/min (4-6 cubic feet per minute) to achieve a concentration of about 18 ppm. This is done to control acid mist. However, during the course of this project ammonia was not added to the flue gas at the request of ABB Environmental Systems, who operated the SNOX process.

2.1.2 SNOX Process

This ICCT demonstration is the Wet Gas Sulfuric Acid (WSA)-Selective Catalytic Reduction of NO_x (SNOX) demonstration by ABB Environmental Systems (*Comprehensive Report to Congress, Clean Coal Technology Program, WSA-SNOX Flue Gas Cleaning Demonstration Project*, U.S. Department of Energy Report No. DOE/FE-0151, November 1989). Cosponsors are the DOE, Ohio Coal Development Office, Ohio Edison, and Snamprogetti, USA. The SNOX process combines selective catalytic reduction and wet sulfuric acid technologies to remove both nitrogen and sulfur oxides from flue gas.

A 35-megawatt equivalent slipstream of flue gas from the Niles Boiler No. 2 is taken after the air preheater and before the ESP to demonstrate the SNOX process. The SNOX system pulls a constant load from Boiler No. 2 as the total load on the boiler fluctuates about full load. The flue gas entering the SNOX process from Boiler No. 2 first passes through a support burner to increase its temperature. The support burner is fueled with natural gas. The combustion air flow is steady, and the flow of natural gas is varied to maintain temperature of the flue gas. The heated flue gas travels to a baghouse to remove particulate matter. After the flue gas leaves the baghouse, ammonia is added to the particle-free gases. The flue gas then passes through the selective catalytic reactor (SCR) where oxides of nitrogen are reduced to free nitrogen and water vapor. The flue gas then passes through the SO₂ reactor where SO₂ is oxidized catalytically to sulfur trioxide and subsequently recovered as sulfuric acid in a wet gas sulfuric acid condenser. The flue gas then rejoins the flue gas from the boiler downstream of the ESP, and exits through the stack.

The SNOX baghouse removes particulate matter from the flue gas stream prior to the SO₂ catalyst. This allows the catalyst, which collects and retains over 90 percent of the particulate matter reaching it, to be used for longer periods of time before cleaning.

The SNOX baghouse was manufactured by ABB Environmental Systems. With a gross air-to-cloth ratio of 3.76 (4.51 net), it has six compartments containing a total of 1,596 Gore-Tex bags. The bags are 431 cm long (169.75") and 15.2 cm (6") in diameter. The bag material is Teflon on fiberglass. New bags were installed in the baghouse several days before sampling began.

Collected particulate matter is dislodged from the bags by pulse jet cleaning several times an hour. The pulse pressure is $3.4\text{--}4.8 \times 10^5$ kPa (50-70 psi). This is automatically initiated by pressure drop sensors. The ash falls into one of six hoppers. The hoppers are dumped once a shift after the ESP hoppers are dumped. The Niles' Station hydro-vac system first empties the ESP hoppers and then automatically empties the SNOX baghouse hoppers. Ash is drawn out of the baghouse hoppers into a sluice line until the low vacuum limit is reached.

After the flue gas leaves the baghouse, it passes through a gas-gas heat exchanger increasing the flue gas temperature. Ammonia is added to the flue gas on a localized scale throughout the cross section of the duct through a matrix of nozzles. An additional 22.65 scm/min (800 scfm) of air flow is added to the flue gas with the ammonia addition. The local concentration ratio of ammonia/nitrogen oxides can be slightly greater than stoichiometric because any unreacted ammonia that passes out of the SCR is oxidized to NO_x, water and nitrogen further downstream in the SO₂ reactor. Throughout this portion of the SNOX process the temperature of the flue gas is above the dew point of ammonium sulfate and ammonium bisulfate. Therefore, no sulfate particulate matter is generated in the flue gas from the ammonia.

The ammonia/flue gas mixture enters the SCR and contacts the Haldor Topsoe DNX monolithic catalyst. The catalyst reduces the NO_x to nitrogen and water vapor.

The flue gas then leaves the SCR and is heated to increase its temperature for optimum conversion of SO₂ in the SO₂ reactor. The SO₂ is converted to SO₃ as it passes through a Haldor Topsoe VK38 sulfuric acid catalyst.

The flue gas then passes through the gas-gas heat exchanger where SO₃ is hydrated to sulfuric acid. The sulfuric acid vapor is condensed in the WSA Condenser. This is a tube and shell falling film condenser with ambient air used as a cooling medium on the shell side. The condenser has 7,200 glass tubes.

The condensed sulfuric acid is fed into an acid conditioning and storage system.

2.2 Process Streams

Eight flue gas, solid and liquid process streams were sampled during the study. In Figure 2-1 the sampling locations are numbered. Table 2-1 identifies the sample locations used for this study. For consistency in handling of samples, a single numbering scheme was applied to three separate field studies conducted by Battelle for DOE, one of which was the SNOX. Thus (e.g.) Location 1 was Boiler Feed Coal for all three studies. A result of this numbering system was that location numbering at the SNOX was non-consecutive, as shown in Table 2-1. Figure 2-1 and Table 2-1 distinguish three types of sampling locations: flue gas/particulate matter sampling locations, designated G; solid sample collection points, designated S; and liquid sample collection points, designated L.

2.2.1 Flue Gas Streams

At the SNOX process sampling for gas and particulate phase species in the flue gas was conducted at four outdoor locations. Battelle staff conducted such sampling at the baghouse inlet (Location 18, Figure 2-1) and baghouse outlet (Location 19). Chester Environmental staff conducted flue gas sampling at the outlet of the SCR unit (Location 20) and outlet of the wet sulfuric acid condenser (Location 21). The flue gas conditions at Locations 18-21 are summarized in Table 2-2.

2.2.1.1 Temperature and Static Pressure. At Locations 18 and 19, the flue gas temperature was in the range 464 to 476 K (376 to 397 F), and the static pressure was slightly negative (0.44 to 0.47 inches mercury).

At Locations 20 (SCR Unit Outlet) and 21 (WSA Condenser Outlet) the flue gas was under positive pressure. The temperature at Location 20 was elevated 624 K (664 F), and the temperature at Location 21 was 365 K (198 F).

2.2.1.2 Moisture. The measured water content of the flue gas was steady throughout the field study. The moisture content measured at Location 21 on July 18 is only one-half of that measured on the remaining days. Review of sampling records did not explain this apparently low result.

2.2.1.3 Oxygen Content. The oxygen content of the flue gas was determined at a single point in the cross section of the duct at each location. The average values for Locations 18-21 were 3.7, 4.3, 6.2, and 6.2 percent, respectively.

2.2.1.4 Particle Loading. Loading of particulate mass in the flue gas streams was determined from samples collected with the Method 29 sampling train during sampling for elements. The average particle mass loading upstream of the SNOX baghouse was 2,170 mg/Nm³ with a relative standard deviation of seven percent. At the exit of the baghouse, the first two determinations were 3.0 and 6.0 mg/Nm³, and the third determination was 40.7 mg/Nm³. Sulfate data for this location track the mass loading (see Section 5). Discussions with ABB Environmental Systems revealed that they have seen elevated mass loadings at the location periodically in other sampling projects. The cause of this phenomenon has not been determined.

The large particle mass loadings listed for Location 20 are believed principally to be artifact formation of ammonium sulfate and ammonium bisulfate in the sampling apparatus. Again the sulfate data at this location are elevated, although sulfate does not account for most of the mass on July 22 and July 24. The mass data were collected as the Method 29 sampling train traversed the duct, while the sulfate data were collected isokinetically at a single point. The non-ideal sampling location (in terms of flow patterns in the duct) is discussed below. This likely had an effect on the results. Again ABB has noted problems with determining flue gas flow rates at Locations 20 and 21 in previous work.

At Location 21, the average mass loading was 49 mg/Nm³. This mass was primarily sulfate, and it may be an artifact of sampling resulting from sulfuric acid mist.

2.2.1.5 Flue Gas Flow Rate. Flow rates at Locations 18 and 19, shown in Table 2-2, agree within about 10 percent, but measured flow rates at Locations 20 and 21 are significantly higher than those at Locations 18 and 19. ABB told Battelle that the measurements at Location 21 are "in line" with work by other contractors, but that these data are not believed to be an accurate determination of the flue gas flow rate following the WSA condenser. A likely explanation for possible flow measurement errors at Locations 20 and 21 is the very poor sampling conditions at these locations.

At Locations 18 and 19, flue gas sampling was conducted from horizontal round ducts about 2 meters (6.5 feet) in diameter and 15 meters (50 feet) above ground. Only two 7.6 cm (3-in.) diameter sampling ports, one vertical and one horizontal, were available at these locations, along with two smaller 2.5-5 cm (or 1-2 inches diameter) ports at Location 19. Along with the very limited platform area at these locations, the small number of ports available made coordination of multiple parallel sampling methods difficult at these locations. Nevertheless these locations had a run of duct in front of them that provided stable flow patterns for determining flue gas flow rates.

At both Locations 20 and 21 multiple horizontal ports were available; however the proximity of the sampling locations to disturbances upstream made these locations less suitable than Locations 18 and 19 for determining mass flows of material in the flue gas. The number of undisturbed upstream diameters at these two locations was zero and one respectively; nowhere near the 10 diameters that is the U.S. EPA standard. These concerns are discussed in Section 3.2.4.

2.2.2 Solid and Liquid Streams

Only one liquid stream was sampled at the SNOX, the sulfuric acid from the WSA condenser (Location 22). Solid samples consisted of baghouse ash (Location 24), SO₂ catalyst waste (Location 23), and boiler feed coal (Location 1). Coal was supplied to the Niles Station by up to six suppliers. As indicated earlier, some blending of coal was done in

the coal year to meet allowable running averages for SO₂ emissions. However, in order to adequately measure coal composition, Ohio Edison staff collected a coal sample from each of the four Boiler No. 2 feeders every half hour of each sampling day while sampling was underway. Those samples were then composited by American Society of Testing and Materials (ASTM) methods to a single sample for that day, about 3 kg of which was provided to Battelle.

2.3 Plant Operating Conditions

The design of the sampling at the SNOX process was based in part of the expected operating conditions of the unit. These conditions are summarized in this section followed by a report on the actual conditions that were encountered.

2.3.1 Nominal Conditions

After consultation with Niles Station and ABB staff, and review of information about the plant, the expected plant operating conditions and allowable ranges of those conditions were established. Table 2-3 lists those operating conditions.

2.3.2 Actual Boiler No. 2 Operating Conditions

During the SNOX field sampling, plant operators provided hourly data on the operating conditions listed in Table 2-3, by filling out log sheets provided by Battelle. Information was also obtained in the form of printouts from the plant data system. Table 2-4 shows the daily averages and standard deviations of Boiler No. 2 operating conditions actually encountered during the six sampling days at the SNOX. These values were calculated from the hourly values recorded during the period of sampling on each sampling day. Copies of the boiler log sheets of operating data from the SNOX sampling periods are included in Appendix A of this report. The process data reported are:

- Coal firing rate
- Load
- Steam generation rate
- Steam temperature
- Steam pressure
- Excess O₂ at the furnace outlet (ahead of air preheater)
- CO₂ at the stack
- SO₂ emissions
- NO_x emissions
- Opacity

Only the hourly data for the actual test period were used in calculating daily average values for plant process variables. The data are summarized in Table 2-4, and they are plotted in Figures 2-2 through 2-11.

The feed rate of crushed coal to the four cyclone burners is determined by Ohio Edison from quantity of coal on the four conveyor belts delivering the coal to the burners along with the speed of travel of the belts. Each belt holds approximately 45 kg/m (30 lb/ft) of coal. The lag time for coal on each of the four conveyor belts (Location 1) to reach the cyclone burners and be fired is a few minutes. The daily average coal firing rate ranged from 11.4 to 11.7 kg/s (90.6 to 93.2 klb/hr), a range of 2.8 percent of the average coal firing rate.

The daily average gross load ranged from 116.2 to 117.2 MW, a range of 0.9 percent of the actual load. The daily average steam generation rate ranged from 109 to 111 kg/s (866 to 882 klb/hr), a range of 1.8 percent of the actual steam generation rate.

The daily average excess oxygen readings at the furnace outlet ranged from 1.07 to 1.70 percent, a range of 45 percent of the excess oxygen.

The Niles Station uses a continuous emission monitoring (CEM) system called Ecoprobe, which was installed by KVB of Irvine, California. The complete system is comprised of two subsystems with one subsystem serving as the primary measurement system and the other as the secondary system. Sulfur dioxide is measured with a Teco 43H pulsed fluorescence analyzer. Nitrogen oxides are measured with a Teco 42

chemiluminescence monitor, and carbon dioxide is measured with a Teco 41H gas filter correlation monitor. The flue gas is diluted by a factor of 150:1 before measurement. There are two flow monitors for the system. The primary system is a Dietrich anubar system, and the secondary system is a Parametrics CEM68 system. The CEMs are calibrated once a day automatically. The primary system is calibrated between 0630 and 0700, and the secondary system is calibrated around noon each day. It was not possible for Research Triangle Institute (RTI) to conduct a performance audit on these CEMs.

The daily average SO₂ emissions ranged from 0.55 to 0.667 g/MJ (1.28 to 1.55 lb/10⁶ Btu), a range of 19 percent of the SO₂ emissions value. The daily average NO_x emissions ranged from 0.28 to 0.34 g/MJ (0.65 to 0.80 lb/10⁶ Btu), a range of 21 percent of the NO_x emissions value. The daily average CO₂ readings at the stack ranged from 13.38 to 13.73 percent, a range of 2.6 percent of the CO₂ value.

The daily average opacity ranged from 2.5 to 3.3 percent, a range of 28 percent of the opacity value.

Comparing the data reported in Table 2-4 to the expected operating conditions given in Table 2-3 shows that the expected load and emissions values were achieved for most parameters. The oxygen value at the furnace outlet deviated from the expected value, but discussions with plant staff after the study suggested that the expected values were too high and that the measured values were more in line with plant practice. The gross load was higher than the "allowable" range listed in Table 2-3. The load was steady, and operation of the plant at a gross load in excess of the range shown in Table 2-3 did not have a negative impact upon the project. Drum steam pressure was higher than the "allowable" range in Table 2-3. This did not have a negative effect on the project.

The only problems encountered in plant operation at the SNOX were in operation of the coal feeders. As Table 2-3 shows, operation with all four feeders and cyclones was required for the sampling effort. This requirement arises because load could drop substantially if one feeder failed. As a result, all flue gas sampling was stopped whenever a feeder was out of service. The most common feeder failure was breakage of a shear pin. This occurred several times during the study, but resulted in sampling interruptions of no more than 15 minutes at a time. Thus this problem caused no deviation from the planned

sampling. A full list of the shear pin occurrences at the SNOX is provided in Section 3.1.3 of this report.

A more serious feeder problem during sampling at the SNOX occurred late in the evening on July 19, when a feeder failed due to bearing problems. The feeder was fixed the morning of July 20, but failed again immediately when put into service. Discussions with plant staff and with the DOE on-site representative led to the conclusion that it would be best to repair the feeder by replacement of appropriate parts. As a result, no sampling was done on July 20, and sampling was delayed until about midday on July 21, after the feeder had been fully repaired. Once fixed, no further serious feeder problems occurred for the rest of the sampling period.

2.3.3 Actual SNOX Operating Conditions

Process data for the SNOX system that are reported are:

- Support burner flow rates
- Gas temperature at baghouse inlet
- Gas temperature at SO₂ reactor inlet
- Gas temperature at WSA condenser outlet
- Ammonia injection rate
- Liquid sulfuric acid production rate
- NO_x at SNOX inlet
- NO_x at SNOX outlet
- SO₂ at SNOX inlet
- SO₂ at SNOX outlet

Data on the support burner flow rates are reported for the entire test period. The actual average flow of natural gas to burners 1 (ahead of Location 18) and 2 (after Location 20) was 0.87 m³/min (0.51 ft³/s) and 0.76 m³/min (0.45 ft³/s) at 86 psi, respectively. These flows correspond to 5.1 dscm/min and 4.5 dscm/min. The flow of natural gas was steady throughout the test period. The average combustion air flow rate to the two burners was 88.75 scm/min and 38.82 scm/min.

Table 2-5 presents average values, ranges, and standard deviations for the other actual SNOX system operating conditions for each day of the study at the SNOX. Selected data are plotted in Figures 2-12 through 2-17. Only the hourly data for the actual test period were used in calculating daily average values for SNOX operating conditions.

Daily average gas temperatures at the baghouse inlet ranged from 469 to 472 K (385 to 390 F), a range of 0.6 percent of the absolute temperature. Daily average gas temperatures at the SNOX reactor inlet were constant at 693 K (788 F), a range of zero percent of the absolute temperature. Daily average gas temperatures at the WSA condenser outlet ranged from 364-365 K (195 to 198 F), a range of 0.3 percent of the absolute temperature.

Daily average ammonia injection rates ranged from 14 to 16.7 g/s (111 to 132 lb/hr), a range of 17 percent of the injection rate. Ammonia injection rates were appreciably higher during the first one and one half days of testing, sometimes reaching 17.7 g/s (140 lb/hr). The high ammonia injection rates caused some sampling problems at Location 20, and the ammonia injection rate was lowered for the remainder of the test. Lowering the ammonia injection rate did not appear to affect NO_x reduction through the SNOX process. The process is designed to be operated at an NH₃/NO_x ratio of slightly greater than stoichiometric.

The rate of production of liquid sulfuric acid in the WSA condenser (Location 22) was on average 210 g/s (1.9 gallons/minute). The daily average rates of production as supplied by ABB Environmental Systems are shown in Table 2-5. A range and standard deviation were not available.

Daily average NO_x values ranged from 671 to 726 ppm at the SNOX inlet and from 45 to 60 ppm at the SNOX outlet. The daily average NO_x value at the SNOX inlet varied by 7.9 percent of the NO_x value at that location, and the daily average NO_x value at the SNOX outlet varied by 29 percent of the NO_x value at that location.

Daily average SO₂ values ranged from 1,936 to 2,102 ppm at the SNOX inlet and from 67 to 83 ppm at the SNOX outlet. The daily average SO₂ value at the SNOX inlet varied by 8.2 percent of the SO₂ value at that location, and the daily average SO₂ value at the SNOX outlet varied by 21 percent of the SO₂ value at that location.

Table 2-6 gives the daily average apparent NO_x and SO₂ reductions, as calculated from the daily average NO_x and SO₂ values. The daily average NO_x reductions ranged from 85 to 93 percent. The daily average SO₂ reductions ranged from 94 to 96 percent.

Research Triangle Institute conducted a performance audit evaluation of ABB's continuous emissions monitors for SO₂ and NO_x and oxygen. The results of the audit are presented in Table 3 of RTI's Field Sampling Audit Report which is included in Appendix B. The difference between the audit standard and ABB's monitors was -2.1 percent for oxygen, 0.40 percent for SO₂ and -0.55 percent for NO_x. These results are within the "reasonable acceptance limit of ± 10 percent" used by RTI in evaluating the performance audit data.

2.3.4 Oxygen in Flue Gas

Excess oxygen in the boiler flue gas characterizes combustion conditions, and oxygen levels in the flue gas as it passes through the control equipment and out the stack is an indication of leakage of ambient air into the flue gas.

The daily average oxygen level in the flue gas at the furnace outlet (ahead of the air preheater) is shown in Table 2-7 (data are from Table 2-4). These data were measured by Ohio Edison at a single point in the duct. The corresponding excess air and total air is shown in the third row.

A calculated value for oxygen content of the flue gas in the stack is shown along with the corresponding excess and total air. These values were calculated from the daily average CO₂ concentrations in the stack and the relationship between oxygen and CO₂. This relationship was calculated from the average coal analysis for the three days and the natural gas consumed by the support burners.

The increase in oxygen content of the flue gas from the outlet of the furnace to the stack is evidence of leakage of ambient air into the flue gas across the air preheater, ESP, and SNOX process as a whole. The Niles Boiler and SNOX process is under negative pressure from the boiler exit through the SNOX baghouse, and leakage of ambient air into the process across the air preheater and perhaps the baghouse can be expected. From the SCR reactor through the exit of the process, the SNOX system is under positive pressure. A

possible source of leakage is a break in any one of the 7,200 glass tubes in the condenser. Implications for air leakage are discussed further in Section 2.3.6.

2.3.5 Barometric Pressure

The barometric pressure on the sampling days was recorded at the flue gas sampling locations. The average reading at these locations for each day is listed in Table 2-8.

2.3.6 Flue Gas Flow Rates

As discussed elsewhere in this section of the report, measurements of the flue gas flow rate at Locations 19, 20, and 21 were suspect because of the potential impact of the configuration of the ducts upstream of these three locations on accurate measurement of the flue gas flow rate. The flow rates at Locations 19, 20, and 21 did not agree with the flow rates at Location 18, even after allowing for natural gas and combustion air introduced into the flue gas downstream of Location 18. Therefore, Battelle decided to base all flow rates used in calculations of material balances, removal efficiencies, and emission factors on the measured flow rates at Location 18. To do this, flow rates were calculated for Locations 19, 20, and 21 adjusting for the differences in oxygen levels and for gases introduced into the system between Locations 20 and 21 (auxiliary burner No. 2 and injection of ammonia). These calculated flows were then compared to the measured flow at Location 18. The tabulation on page 2-14 shows the calculated flow rates for Locations 19, 20, and 21 and the impact of the air added with the ammonia and auxiliary burner No. 2.

Average Values for Flue Gas	Dry Flue Gas Flow Rate	
	lb/hr	kg/hr
Location 18 - measured	315,082	142,894
Presumed air leakage	11,184	5,072
Location 19 - calculated	326,266 ^(a)	147,966
Air added with ammonia	3,662	1,661
Presumed air leakage	37,499	17,006
Location 20 - calculated	367,427 ^(a)	166,634
Flue gas generated by burner No. 2	5,239	2,376
Presumed air leakage	10,894	4,941
Location 21 - calculated	383,560 ^(a)	173,950

(a) Calculated from the measured flow rate at Location 18, the oxygen level, and input of air and natural gas.

From the information presented above it can be seen that there is flow of gas that is unaccounted for between each set of locations. In other words there is flow of flue gas that is not intentionally introduced in the SNOX process; leakage of ambient air into the system is thought to be the cause of the increased flow rate and oxygen concentration. Between Locations 18 and 19, the baghouse operates at a negative pressure with respect to ambient conditions. The presumed air leakage (about 3.4 percent of the total flow) between Location 18 and Location 19 might be the result of leakage of ambient air into the baghouse.

Between Locations 19 and 20 of the SNOX system, the flow of flue gas that is presumed to be air leakage is 17,006 kg/hr (37,499 lb/hr). Components of the SNOX system between these two locations include a fan, a gas to gas heat exchanger, ammonia injection equipment, and the SCR reactor. The SCR reactor is under positive pressure. A location for leakage of ambient air into the SNOX system was not identified.

Between Locations 20 and 21 the components of the SNOX system include the second support burner, SO₂ reactor, gas-to-gas heat exchanger, and WSA condenser. A possibility for leakage of air into this portion of the SNOX process is a break in one or more of the 7,200 glass tubes in the condenser.

The calculations leading to the flue gas flows at Locations 19, 20, and 21 depend, of course, upon the measured levels of oxygen. To the extent that these measurements do not

accurately represent flue gas conditions, an error would be introduced into the calculated flow rates. The oxygen measurements were made at a single location in the duct at each sampling location. The oxygen levels at Locations 20 and 21 would have had to have been about two percent lower to eliminate the unaccounted flow of flue gas between these two locations.

In summary, calculations based upon the measured flow rate at the inlet to the baghouse (Location 18); measured oxygen levels at Locations 19, 20, and 21; and injection of natural gas and air were used to estimate the flue gas flow rates at Locations 19, 20, and 21. These calculations indicate that additional flow of gases entered the system between each pair of locations. This additional flow may be explained by leakage of ambient air into the SNOX process.

TABLE 2-1. IDENTIFICATION OF SAMPLING POINTS

Location ^(a)	Description	SNOX
1	Boiler feed coal	S
18	Baghouse inlet	G
19	Baghouse outlet	G
20	SCR unit outlet	G
21	WSA condenser outlet	G
22	Sulfuric acid	L
23	SO ₂ catalyst waste	S
24	Baghouse ash	S

- (a) See Figure 2-1 for locations in the process streams at the SNOX process.
- (b) S = solid stream, G = flue gas stream, L = liquid stream.

TABLE 2-2. FLUE GAS CHARACTERISTICS AT SAMPLING LOCATIONS

Location/ Test Day	Flue Gas Characteristics						
	Temperature (K)	Pressure (mm Hg)	Moisture (percent)	Oxygen (percent)	Particle Loading ^(a,d) (mg/Nm ³)	Flue Gas Flow Rate ^(c,e) (Nm ³ /min)	Flue Gas Flow Rate ^(c,e) (Nm ³ /min)
Location 18							
Baghouse Inlet							
7/18	475	-11.9	8.8	4.0	— ^(b)	1,715	1,817
7/19	474	-11.9	10.8	4.2	2,213	1,679	1,800
7/21	476	-11.9	8.2	4.5	—	1,695	1,850
7/22	475	-11.9	9.2	3.5	2,019	1,717	1,767
7/23	478	-11.9	7.0	2.8	—	1,815	1,794
7/24	472	-11.9	8.9	3.0	2,265	1,747	1,747
Location 19							
Baghouse Outlet							
7/18	468	-11.2	8.9	4.8	—	1,482	1,647
7/19	464	-11.2	10.3	4.2	3.0	1,509	1,617
7/21	465	-11.2	8.3	4.3	—	1,501	1,618
7/22	466	-11.2	9.3	4.0	6.0	1,500	1,589
7/23	466	-11.2	6.9	4.0	—	1,523	1,613
7/24	466	-11.2	9.3	4.5	40.7	1,450	1,582
Location 20							
SCR Unit Outlet							
7/18	628	30.5	8.9	6.0	—	3,217	3,865
7/19	619	30.5	10.1	6.0	349	2,553	3,067
7/21	623	30.5	8.3	6.5	—	2,477	3,078
7/22	624	30.5	8.9	6.0	248	3,249	3,903
7/23	624	30.5	8.3	7.0	—	3,087	3,975
7/24	624	30.5	8.7	6.0	360	3,010	3,616
Location 21							
WSA Condenser Outlet							
7/18	364	1.52	7.9	5.0	—	1,789	2,014
7/19	365	1.52	9.0	6.0	61	1,694	2,035
7/21	364	1.52	8.0	7.0	—	1,636	2,107
7/22	365	1.52	8.1	6.0	32	1,419	1,705
7/23	365	1.52	7.8	5.0	—	1,830	2,060
7/24	366	1.52	8.0	8.0	55	1,406	1,951

- (a) The particle loading at Location 20 is believed to be ammonium sulfite and/or sulfate salts that were generated from the ammonia addition to the flue gas. The particle mass loadings at Location 21 may be sulfuric acid mist.
- (b) Particle mass loading was measured on days when a Method 29 sampling train was used to collect material for elemental analysis. It was not measured on days when samples were collected for organic analyses.
- (c) The measured flue gas flow rate at Location 20 is much higher than at Locations 18 and 19. Sampling at Location 20 was far from ideal coming in a rectangular duct just a few feet after a 180-degree bend. In addition, not all ports could be accessed. Therefore, the measured flue gas flow rates based upon traversing are subject to considerable uncertainty. The flue gas flow rates at Location 21 are also higher than at Locations 18 and 19.
- (d) Normalized to three percent oxygen in flue gas.
- (e) Flow rate at actual oxygen content.

TABLE 2-3. NILES BOILER NO. 2 AND SNOX EXPECTED OPERATING CONDITIONS AND PERMITTED DEVIATION

Parameter ^(a)	Nominal Expected Value	Allowable Range
Boiler Operating Conditions		
Coal	Constant source, if possible	
Load, MW (gross)	115	110-115
Cyclones in operation	4	4
Flue gas oxygen monitor readings, percent	2.5-3.0	1.8-3.0
Steam temperature at superheater outlet, F	1000	980-1010
Steam temperature at reheater outlet, F	1000	950-1010
Drum steam pressure, psig	1470	1460-1480
Throttle steam flow, lb/hr	850,000- 900,000	800,000- 1,000,000
Preheater dumping	Arranged schedule	
ESP dumping	Arranged schedule	
Emissions		
Stack opacity, 6-min. average, percent	3-10	< 20
Stack SO ₂ , ppm	1900	1800-2200
Stack NO _x , ppm	600-650	500-810
SNOX operating conditions		
Gas temperature at baghouse inlet, F	400	385-415
Gas temperature at SO ₂ reactor inlet, F	788	780-800
Gas temperature at SO ₂ condenser outlet, F	205	195-210
NO _x reduction through SNOX system, percent	> 90 ^(b)	90-100
SO ₂ reduction through SNOX system, percent	96	90-100
Discharge NO _x , ppm	40-50 ^(b)	Actual

(a) 1,000 F = 811 K	1,000,000 lb/hr = 126 kg/s
980 F = 800 K	385 F = 469 K
1,010 F = 816 K	400 F = 478 K
950 F = 783 K	415 F = 487 K
1,470 psig = 1.01 x 10 ⁷ kPa	780 F = 689 K
1,460 psig = 1.01 x 10 ⁷ kPa	788 F = 693 K
1,480 psig = 1.02 x 10 ⁷ kPa	800 F = 700 K
800,000 lb/hr = 101 kg/s	195 F = 364 K
850,000 lb/hr = 107 kg/s	205 F = 369 K
900,000 lb/hr = 114 kg/s	210 F = 372 K

(b) These values were reported incorrectly as >95% and 5 ppm in the site-specific Sampling Plan.

TABLE 2-4. ACTUAL OPERATING CONDITIONS FOR NILES BOILER
NO. 2 DURING SAMPLING

Date	Average	Range	Standard Deviation
<u>Coal Firing Rate, klb/hr</u>			
July 18	93.2	92.0-94.3	0.6
July 19	91.7	90.3-93.3	1.1
July 21	91.0	89.2-92.9	1.2
July 22	92.2	91.2-93.1	0.6
July 23	90.8	89.9-92.6	0.8
July 24	90.6	89.6-91.6	0.6
<u>Load, MW</u>			
July 18	116.3	115-117	0.6
July 19	116.2	116-117	0.4
July 21	116.6	115-118	0.9
July 22	117.0	117-117	0.0
July 23	117.0	117-117	0.0
July 24	117.2	117-118	0.3
<u>Steam Generation Rate, klb/hr</u>			
July 18	866	863-868	1
July 19	868	867-870	1
July 21	878	874-882	3
July 22	879	876-880	1
July 23	882	879-886	3
July 24	876	872-879	2
<u>Drum Steam Pressure, psig</u>			
July 18	1533	1531-1535	1.3
July 19	1534	1532-1536	1.2
July 21	1535	1534-1537	1.1
July 22	1536	1534-1538	1.4
July 23	1537	1535-1538	1.1
July 24	1536	1534-1537	1.2
<u>Steam Temperature at Superheater Outlet, F</u>			
July 18	1000	999-1002	0.7
July 19	1000	996-1002	1.6
July 21	995	986-1000	4.0
July 22	998	995-1000	1.7
July 23	997	991-1000	3.4
July 24	1000	999-1000	0.5
<u>Steam Temperature at Reheater Outlet, F</u>			
July 18	982	973-987	4.9
July 19	976	964-982	6.5
July 21	971	952-984	9.6
July 22	972	965-975	2.9
July 23	965	960-968	3.2
July 24	979	969-985	4.6

TABLE 2-4. (Continued)

Date	Average	Range	Standard Deviation
<u>Excess O₂ at Furnace Outlet, percent[#]</u>			
July 18	2.04	1.57-2.44	0.25
July 19	1.80	1.56-2.27	0.20
July 21	2.20	1.98-2.46	0.19
July 22	1.78	1.64-2.01	0.13
July 23	1.57	1.32-1.70	0.12
July 24	2.10	1.78-2.51	0.23
<u>CO₂ at Stack, percent[#]</u>			
July 18	13.38	13.17-13.59	0.14
July 19	13.48	13.31-13.62	0.09
July 21	13.46	13.24-13.65	0.13
July 22	13.65	13.59-13.71	0.05
July 23	13.73	13.63-13.78	0.05
July 24	13.45	13.30-13.80	0.17
<u>SO₂ Emissions, lb/10⁶ Btu</u>			
July 18	1.31	1.25-1.39	0.05
July 19	1.28	1.10-1.36	0.07
July 21	1.52	1.21-1.65	0.13
July 22	1.31	1.25-1.34	0.03
July 23	1.39	1.26-1.53	0.08
July 24	1.55	1.45-1.64	0.07
<u>NO_x Emissions, lb/10⁶ Btu</u>			
July 18	0.76	0.60-0.87	0.08
July 19	0.65	0.56-0.69	0.04
July 21	0.79	0.71-0.90	0.07
July 22	0.78	0.70-0.87	0.05
July 23	0.71	0.69-0.75	0.02
July 24	0.80	0.71-0.89	0.06
<u>Opacity, percent</u>			
July 18	3.3	3.0-11.2	0.75
July 19	2.7	2.3-10.6	0.84
July 21	2.9	2.6-5.8	0.43
July 22	2.2	0-8.6	9.4
July 23	3.4	0.3-15.6	1.8
July 24	3.3	2.9-3.6	0.15

* 0.5 percent was added to the oxygen readings reported by Ohio Edison instrumentation because the utility stated that the observed readings were about 0.5 percent low.

Values reported on a wet flue gas basis.

TABLE 2-5. ACTUAL OPERATING CONDITIONS FOR THE SNOX
PROCESS DURING SAMPLING

Date	Average	Range	Standard Deviation
<u>Gas Temperature, Baghouse Inlet, F</u>			
July 18	388	383-395	4.3
July 19	387	381-390	2.9
July 21	385	383-388	1.8
July 22	387	385-389	1.0
July 23	390	384-398	3.8
July 24	386	382-391	3.1
<u>Gas Temperature, SO₂ Reactor Inlet, F</u>			
July 18	788	787-790	0.9
July 19	788	786-789	0.9
July 21	788	786-790	1.2
July 22	788	786-790	1.0
July 23	788	786-790	1.1
July 24	788	786-790	0.9
<u>Gas Temperature, WSA Condenser Inlet, F</u>			
July 18	506	504-508	1.2
July 19	504	503-506	0.7
July 21	505	504-507	0.9
July 22	504	501-505	1.1
July 23	505	501-507	1.6
July 24	504	503-505	0.5
<u>Gas Temperature, WSA Condenser Outlet, F</u>			
July 18	196	191-199	2.3
July 19	197	193-203	2.8
July 21	195	188-198	2.8
July 22	195	191-198	1.9
July 23	195	193-199	1.8
July 24	198	193-206	3.1
<u>Ammonia Injection Rate, g/s</u>			
July 18	16.7	15.4-17.7	
July 19	16.3	14.8-17.7	
July 21	14.9	14.3-15.4	
July 22	14.4	12.4-16.3	
July 23	14.5	14.0-14.9	
July 24	14.0	13.2-14.8	
<u>Liquid Sulfuric Acid Production, g/s</u>			
July 18	200		
July 19	200		
July 21	210		
July 22	210		
July 23	230		
July 24	200		

TABLE 2-5. (Continued)

Date	Average	Range	Standard Deviation
<u>NO_x at SNOX Inlet, ppm</u>			
July 18	726	687-753	21
July 19	707	679-728	14
July 21	671	650-702	15
July 22	692	671-727	17
July 23	679	665-696	8
July 24	684	651-716	18
<u>NO_x at SNOX Outlet, ppm</u>			
July 18	45	39-56	5.5
July 19	60	39-43	1.1
July 21	49	43-60	5.3
July 22	56	41-68	8.3
July 23	49	42-57	4.6
July 24	55	43-71	8.0
<u>SO₂ at SNOX Inlet, ppm</u>			
July 18	2039	1959-2138	53
July 19	2086	1955-2208	69
July 21	2102	1915-2408	130
July 22	1936	1885-1998	26
July 23	2071	1943-2156	59
July 24	2061	1969-2174	64
<u>SO₂ at SNOX Outlet, ppm</u>			
July 18	81	74-92	4.3
July 19	83	77-93	4.4
July 21	78	67-96	8.4
July 22	67	59-74	3.9
July 23	76	71-83	3.6
July 24	68	56-79	6.0

TABLE 2-6. REMOVAL EFFICIENCY OF THE SNOX PROCESS FOR NO_x AND SO₂ DURING SAMPLING AND FRACTION OF BOILER FLUE GAS TREATED BY THE SNOX PROCESS

	Average Removal Efficiency (Percent)		Boiler Flue Gas Treated by SNOX (Percent)
	NO _x	SO ₂	
July 18	93	95.6	28.3
July 19	88	94.8	28.1
July 21	91	95.5	28.7
July 22	89	95.2	28.6
July 23	92	95.7	30.7
July 24	85	94.0	29.6

TABLE 2-7. OXYGEN CONTENT OF FLUE GAS AT FURNACE
EXIT AND STACK (values in percent)

Parameter	July 18	July 19	July 20	July 22	July 23	July 24	Average
<u>Oxygen</u>							
Furnace Outlet ^(a)	2.0	1.8	2.2	1.8	1.6	2.1	1.9
Location 18	4.0	4.2	4.5	3.5	2.8	3.0	3.7
Location 19	4.8	4.2	4.3	4.0	4.0	4.5	4.3
Location 20	6.0	6.0	6.5	6.0	7.0	6.0	6.3
Location 21	5.0	6.0	7.0	6.0	5.0	8.0	6.2
Stack ^(b)	5.6	5.5	5.5	5.3	5.2	5.5	5.4
<u>(Excess Air) Total Air^(c)</u>							
Furnace Outlet ^(a)	(11)111	(9)109	(12)112	(9)109	(8)108	(11)111	(10)110
Location 18	123	125	127	120	115	117	121
Location 19	129	125	125	123	123	127	125
Location 20	139	139	144	139	149	139	142
Location 21	130	139	149	139	130	160	141
Stack ^(b)	136	135	135	133	132	135	134

(a) Measured by Ohio Edison.

(b) Calculated from coal analysis and stack CO₂.

(c) Based upon oxygen concentrations.

TABLE 2-8. BAROMETRIC PRESSURE AT THE SNOX SITE

Date	Kilo Pascal		Inches Hg	
	Average	SD	Average	SD
July 18	9.857x10 ⁴	400	29.22	0.12
July 19	9.820x10 ⁴	510	29.11	0.15
July 21	9.830x10 ⁴	440	29.14	0.13
July 22	9.837x10 ⁴	440	29.16	0.13
July 23	9.847x10 ⁴	440	29.19	0.13
July 24	9.847x10 ⁴	440	29.19	0.13

SD = Standard deviation.

Average is the average of readings made once at three sampling locations.

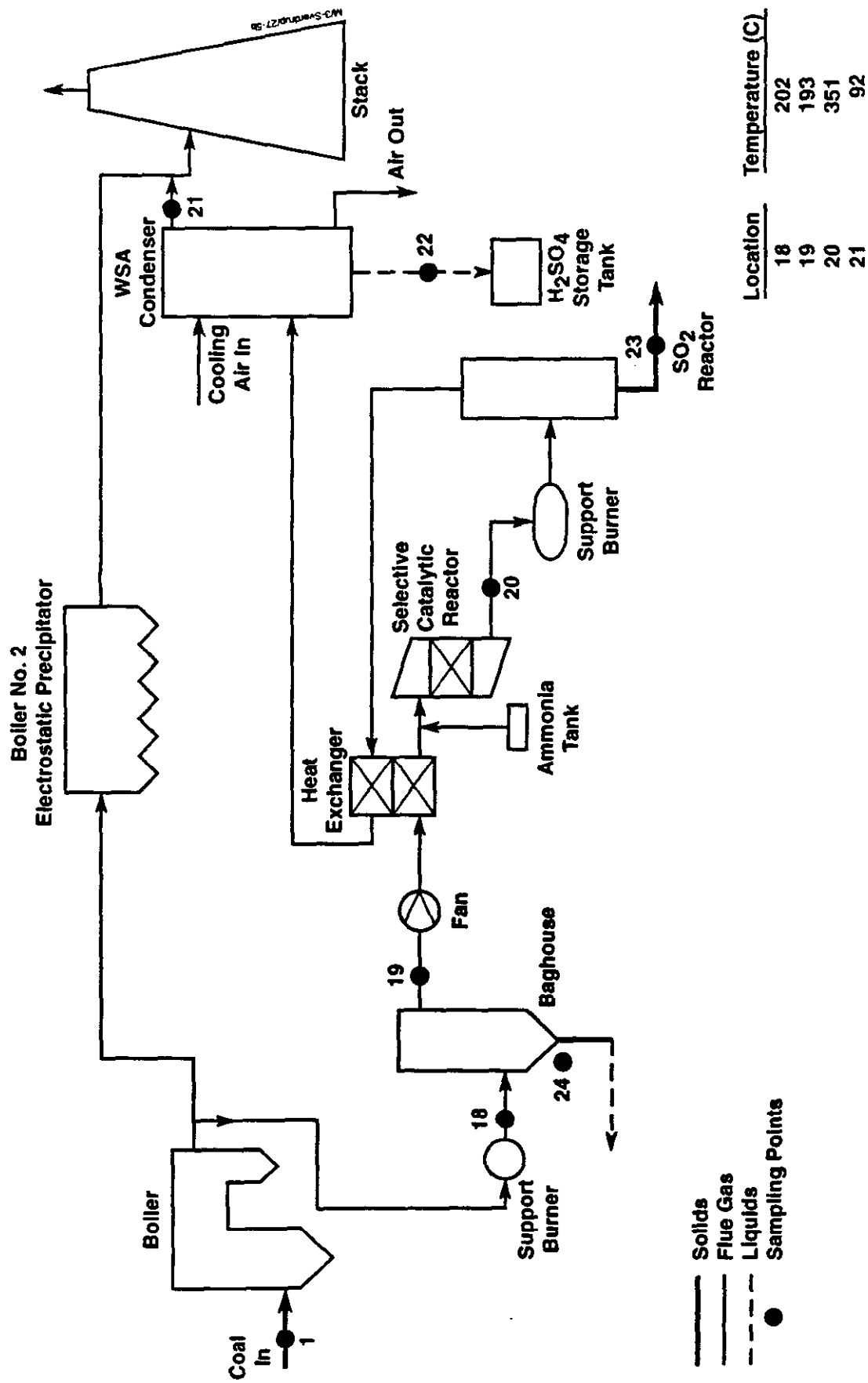


Figure 2-1. Process flow diagram and sampling locations for the SNOX process

SNOX

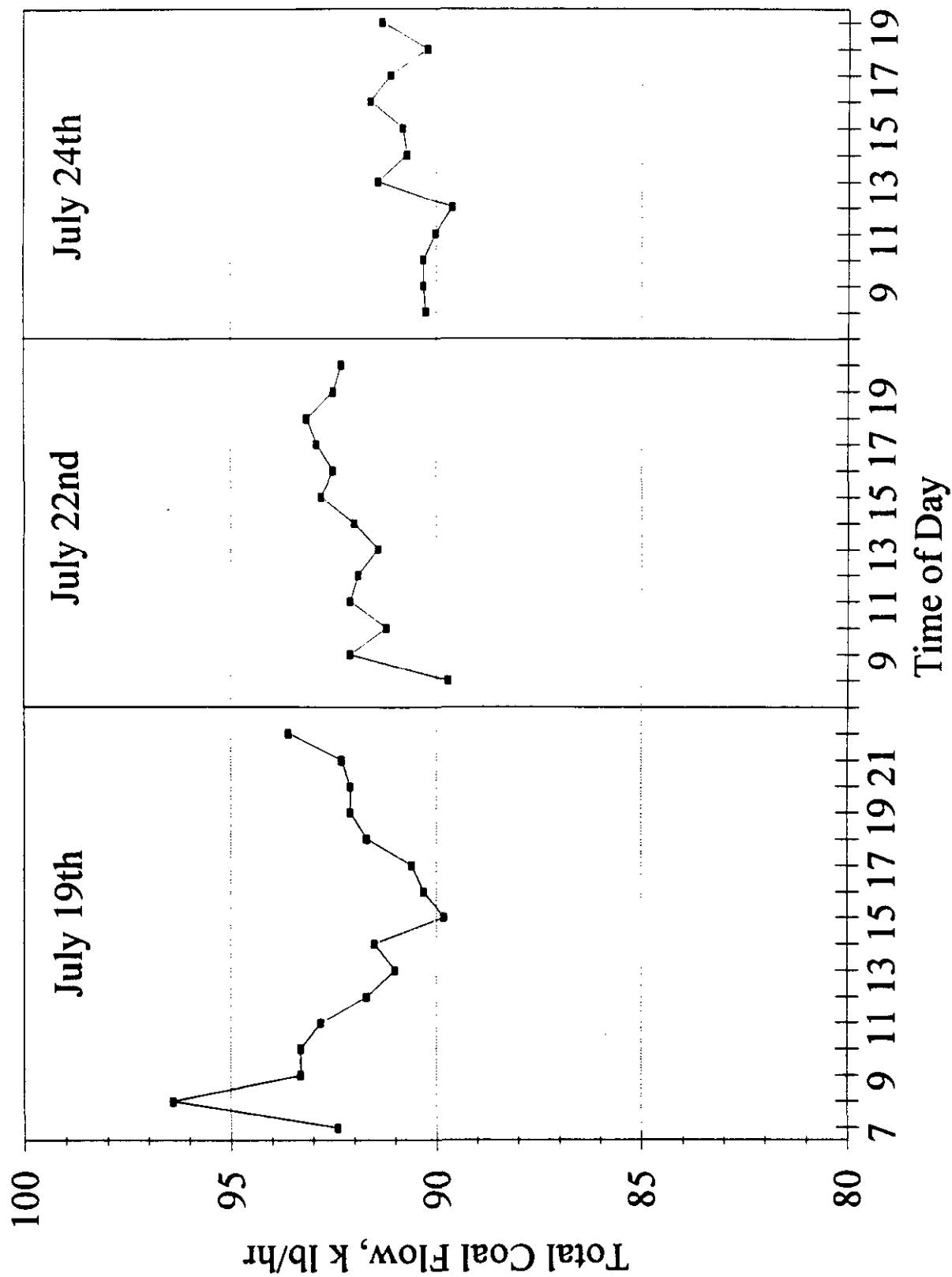


Figure 2-2. Coal feed rate to Niles Boiler No. 2 on inorganic sampling days

SNOX

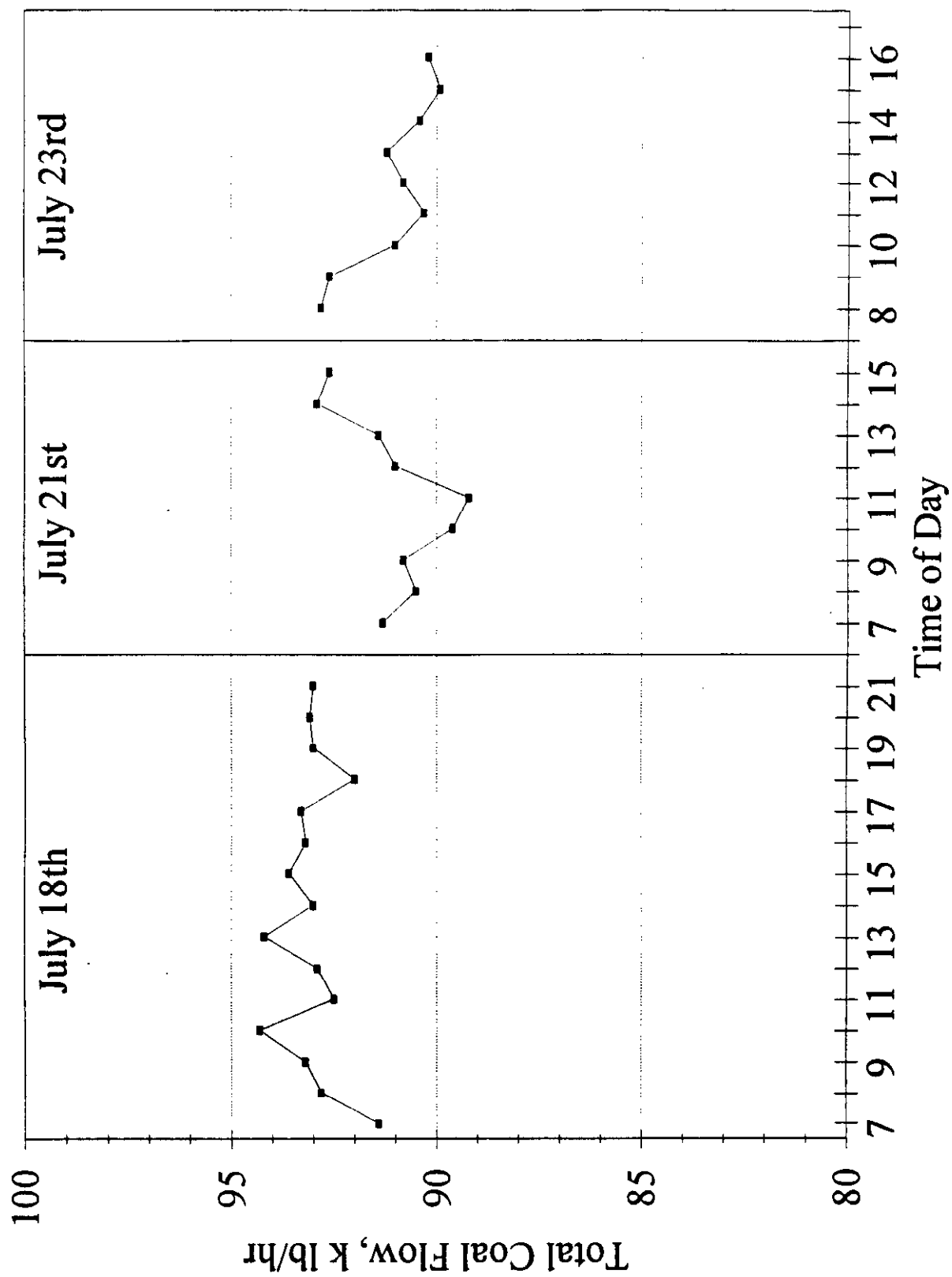


Figure 2-3. Coal feed rate to Niles Boiler No. 2 on organic sampling days

SNOX

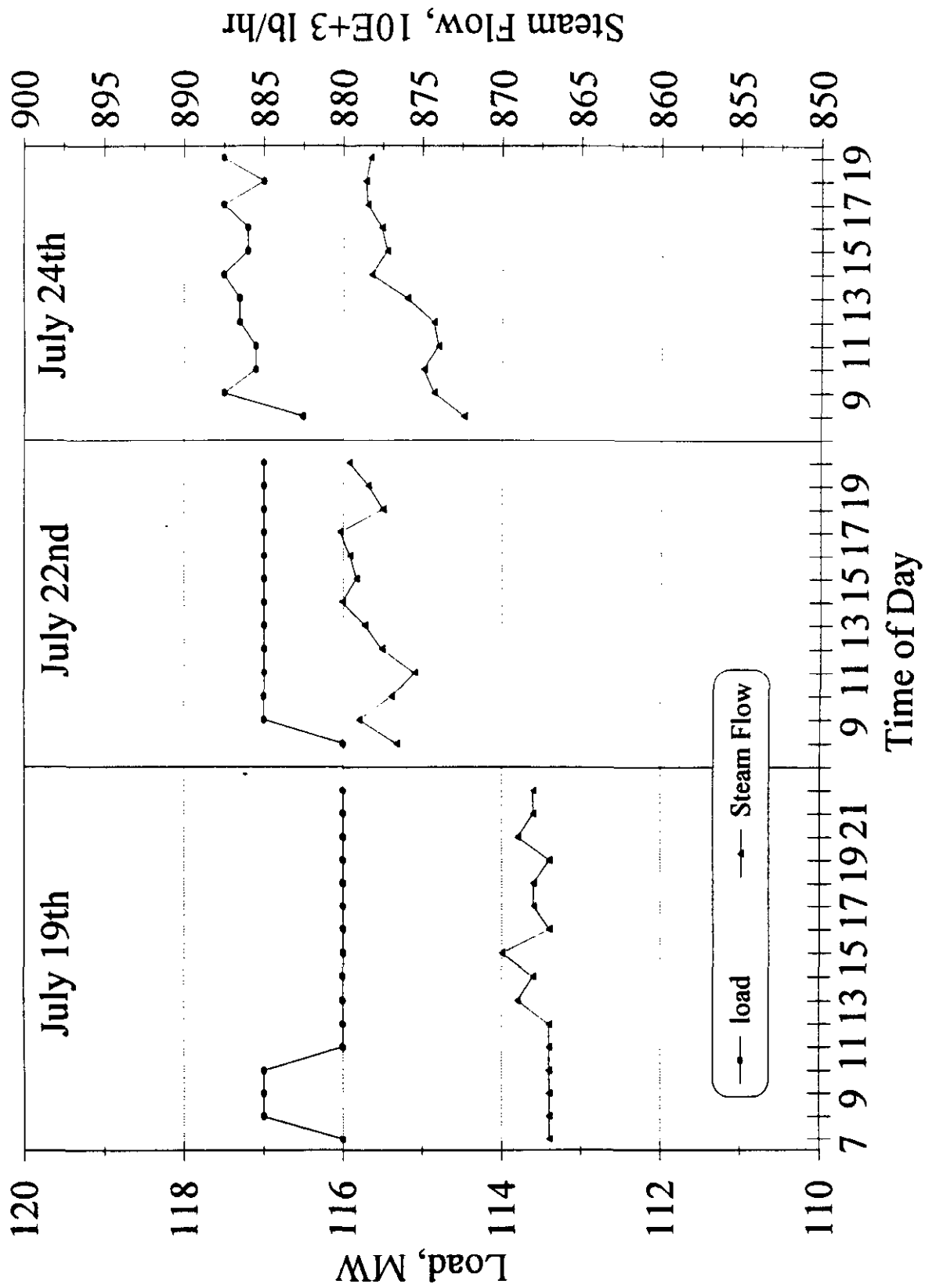
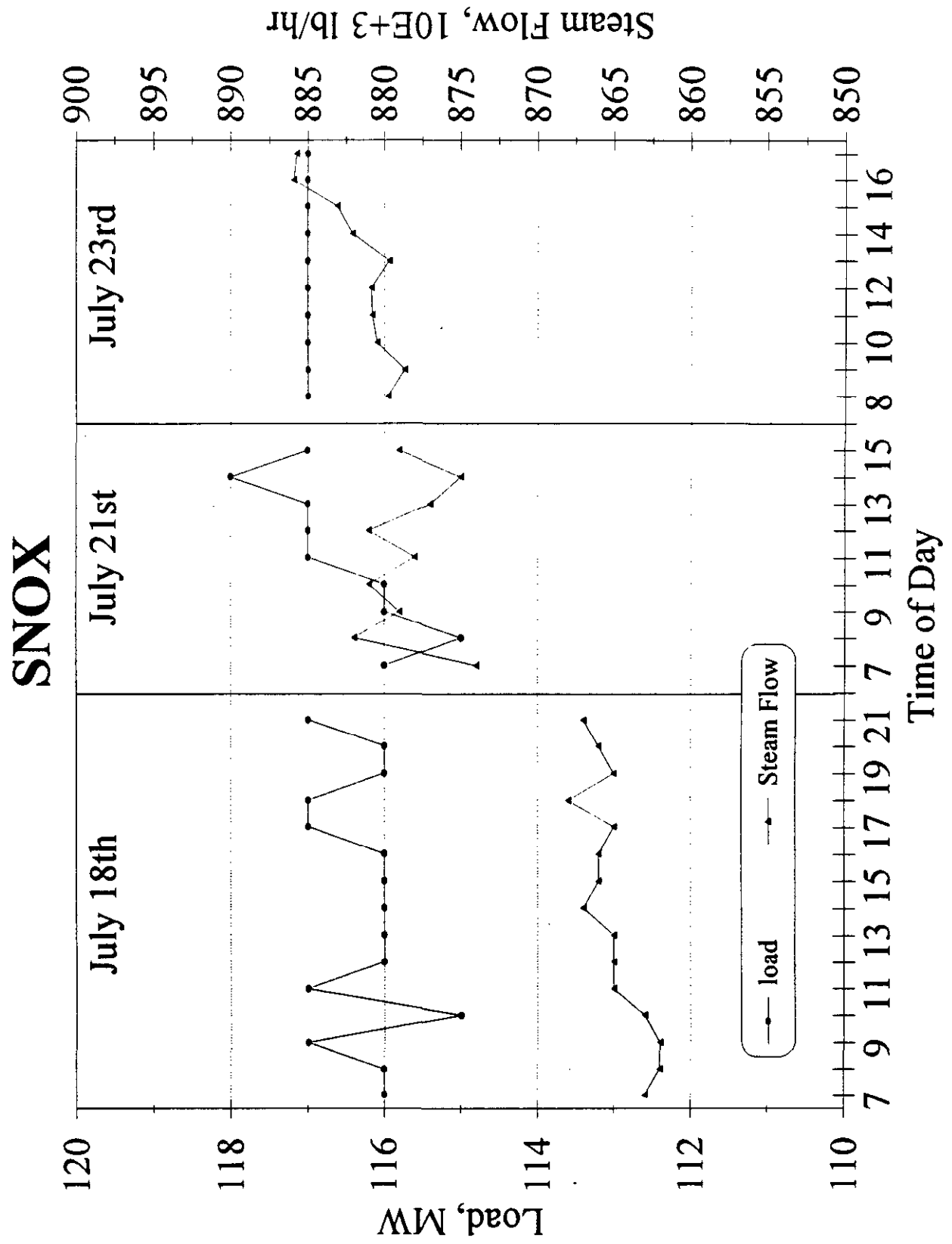


Figure 2-4. Load and steam generation rate on inorganic sampling days



SNOX

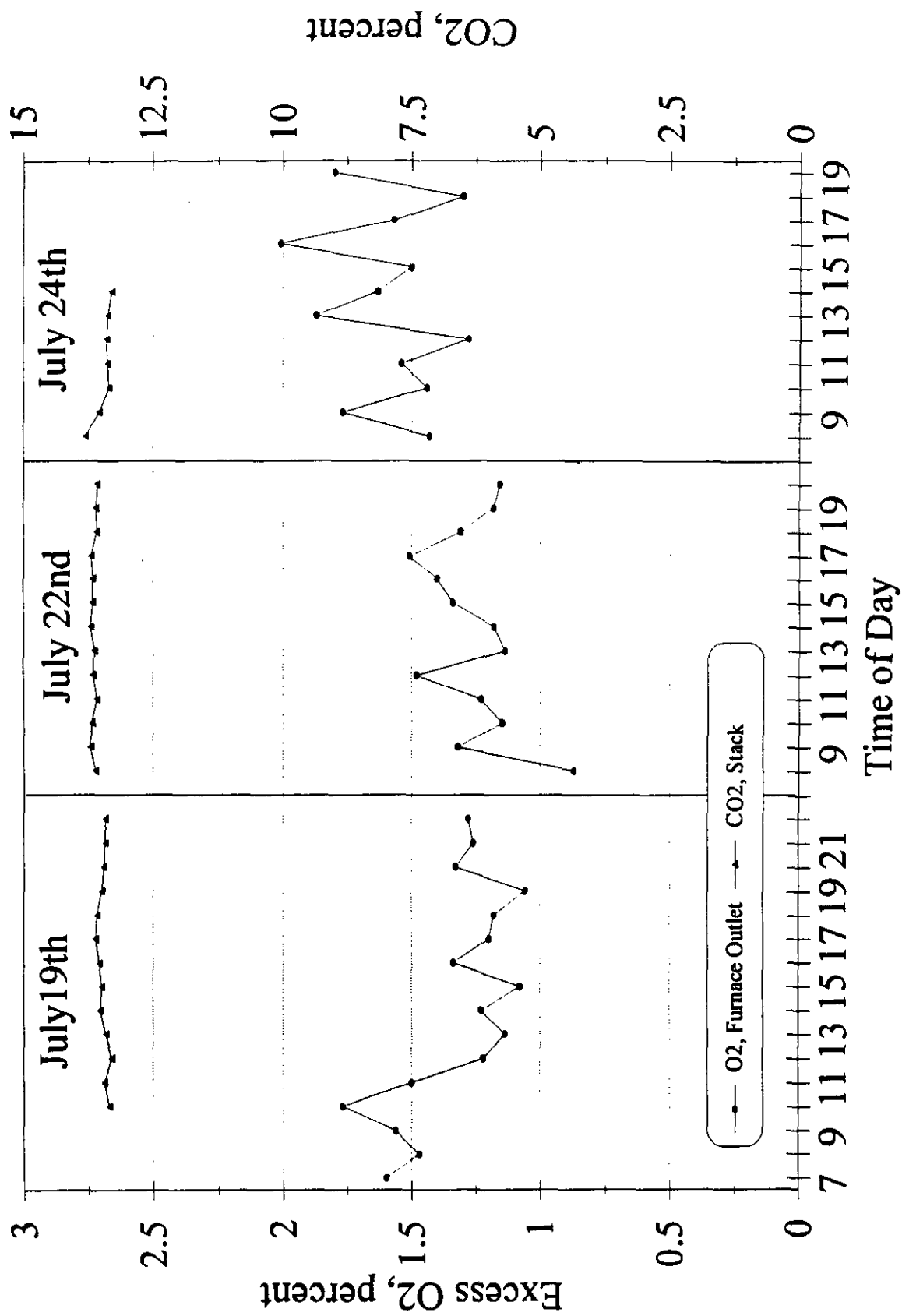


Figure 2-6. Furnace outlet O₂ and stack CO₂ on inorganic sampling days

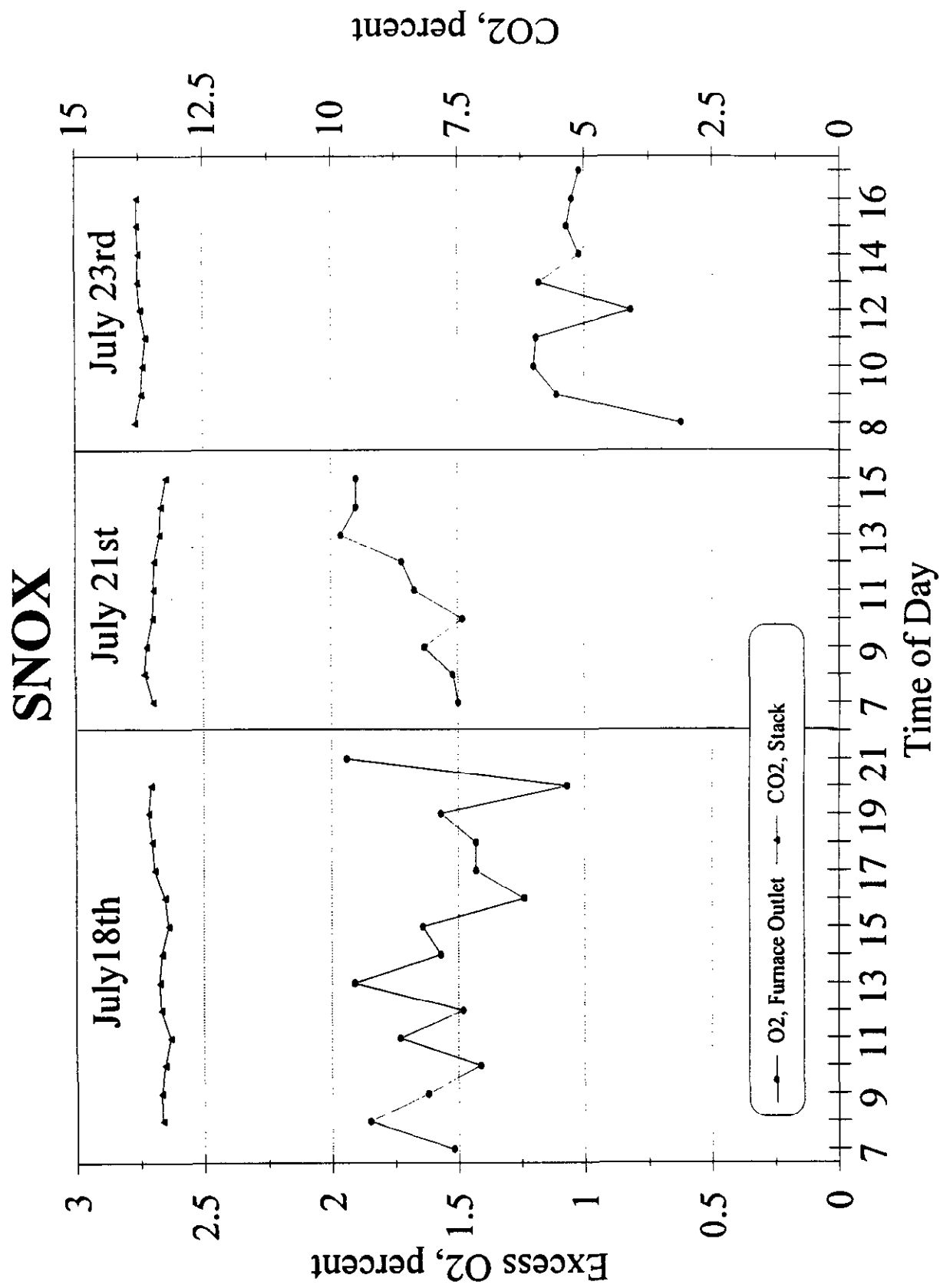


Figure 2-7. Furnace outlet O₂ and stack CO₂ on organic sampling days

SNOX

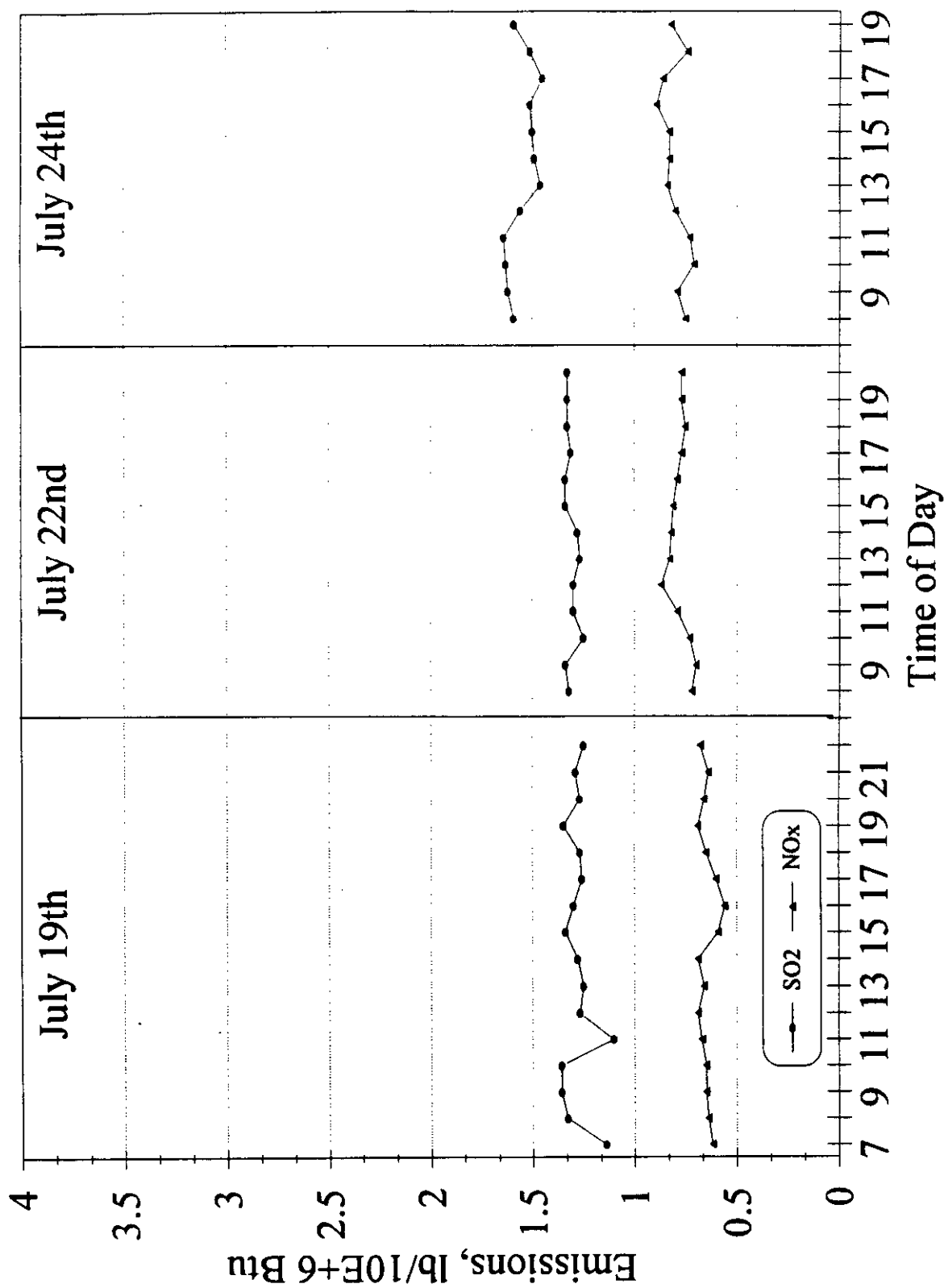


Figure 2-8. Unit No. 2 SO₂ and NO_x emissions on inorganic sampling days

SNOX

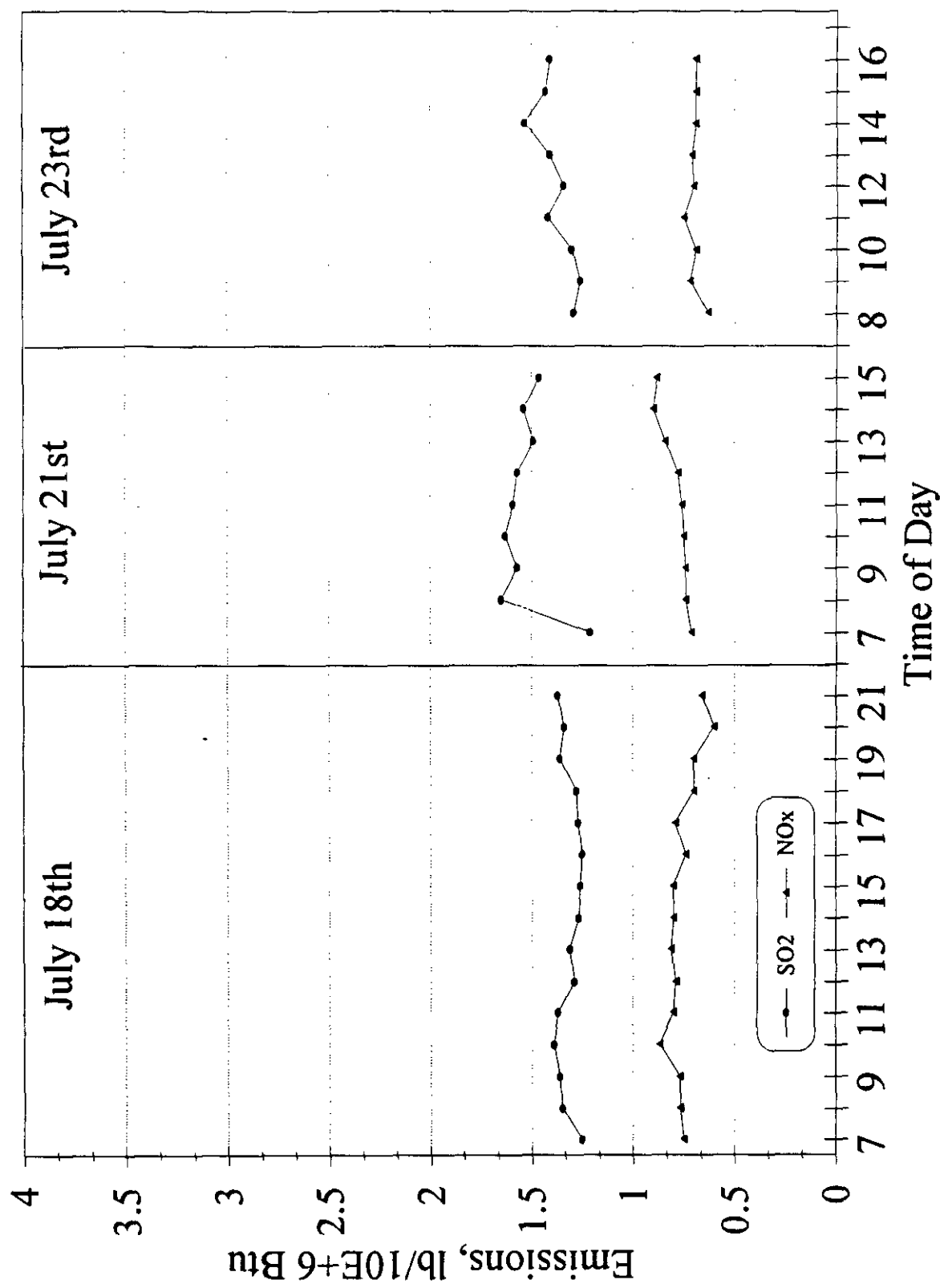


Figure 2-9. Unit No. 2 SO₂ and NO_x emissions on organic sampling days

SNOX

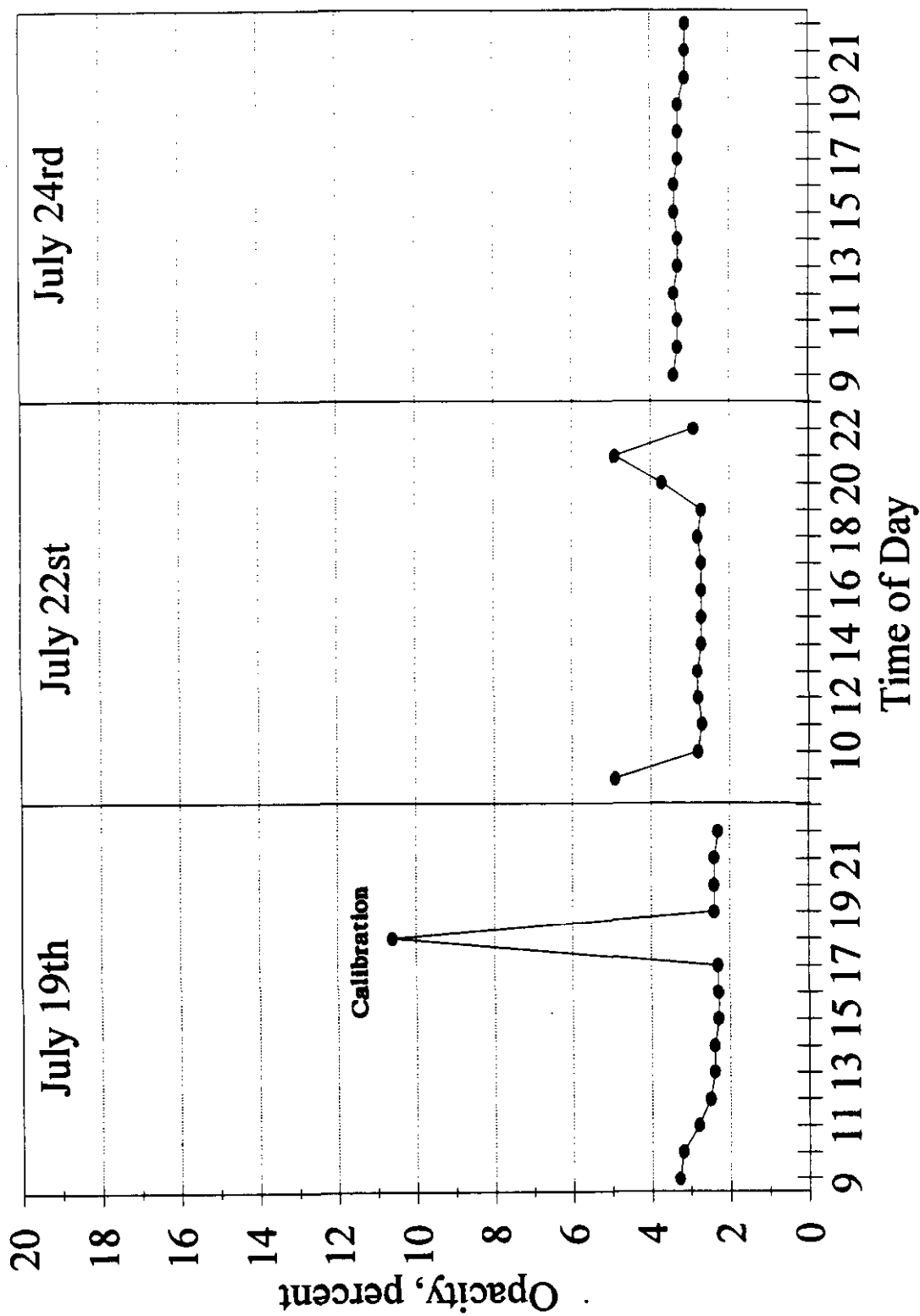


Figure 2-10. Unit No. 2 opacity on inorganic sampling days

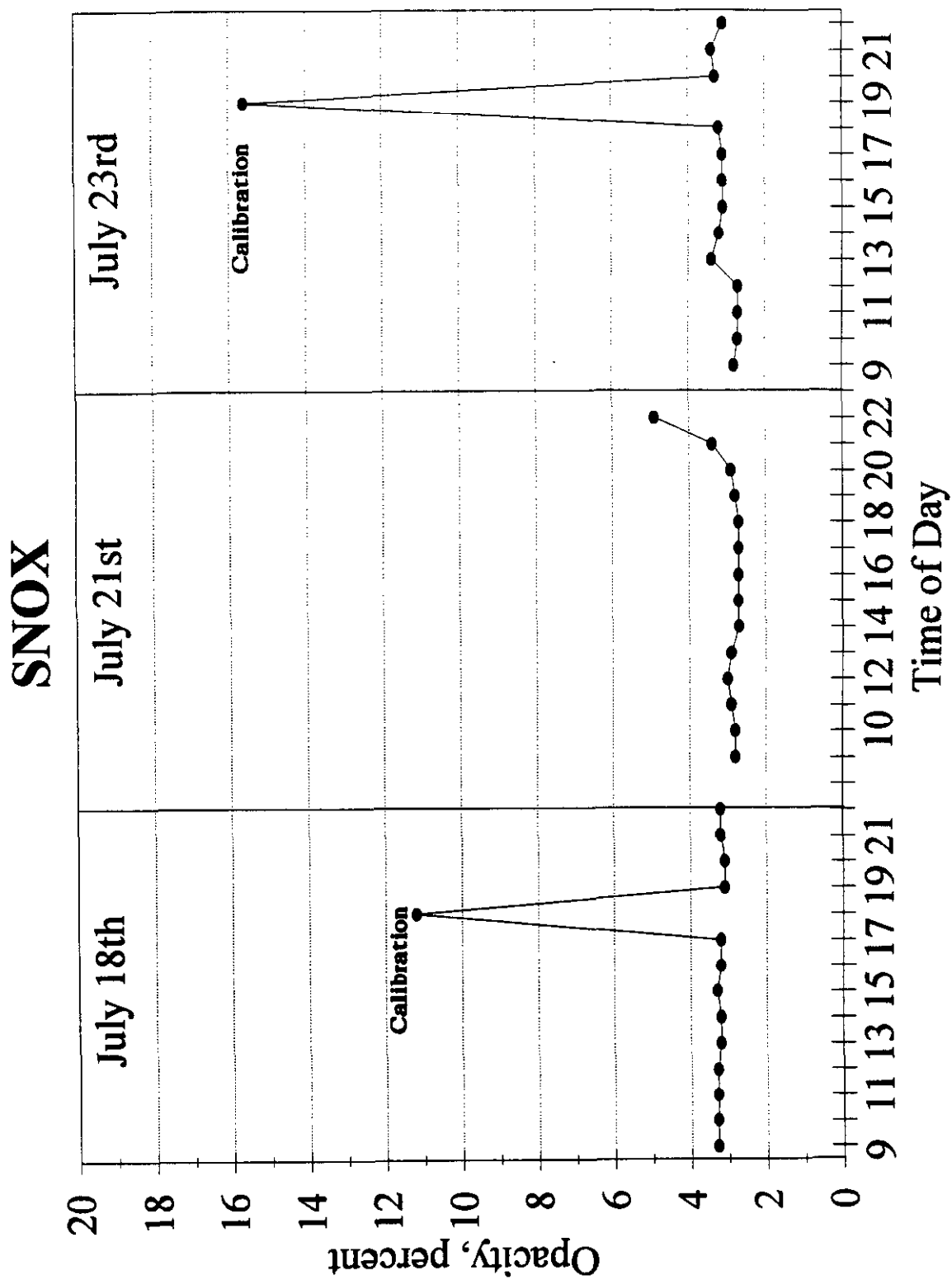


Figure 2-11. Unit No. 2 opacity on organic sampling days

150

uly 24th

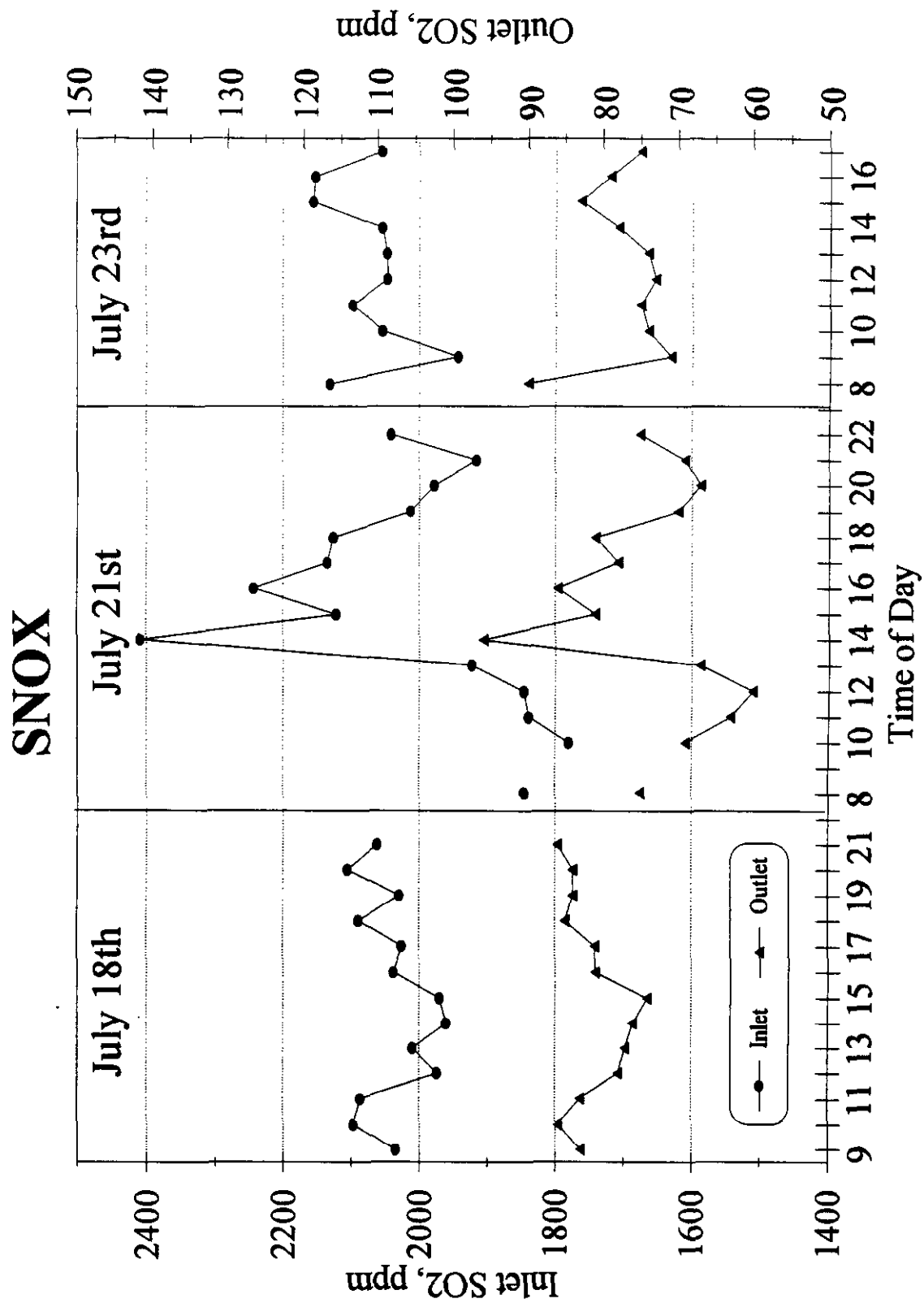


Figure 2-13. SNOX inlet and outlet SO₂ on organic sampling days

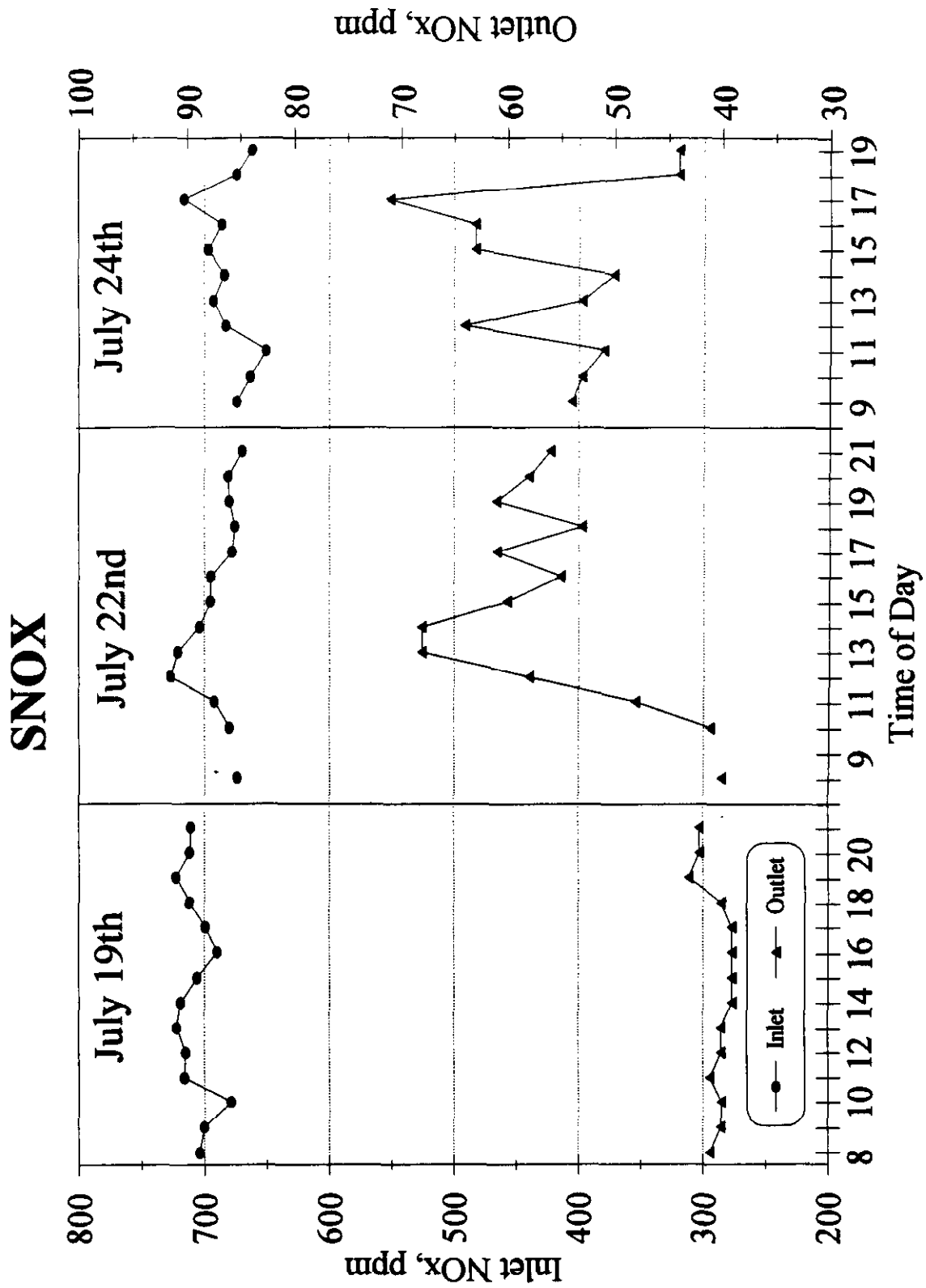


Figure 2-14. SNOX inlet and outlet NO_x on inorganic sampling days

3.1.3 Deviations and Modifications to Schedule

During sampling at the SNOX process, one serious problem occurred, having to do with one of the coal feeders on Boiler No. 2. After completion of all sampling on July 19, one of the coal feeders failed. Ohio Edison (OE) staff worked to fix the feeder and brought it back on line on the morning of July 20, but it failed again immediately. After consultation with OE staff and with the DOE on-site representative, the decision was made to cancel sampling for the day, allow OE staff to undertake proper repairs, and begin again the next day. Repairs of the feeder took until about mid-day on July 21, at which time normal operation of the plant resumed. The start of sampling on July 21 was delayed until about 1300 h to be sure of proper feeder operation.

In addition to the failure of the feeder on July 19-20, several small interruptions in sampling occurred due to breakage of shear pins on the feeders of Boiler No. 2. Since loss of a feeder due to a broken shear pin affects plant load and operating conditions, sampling was stopped when a sheared pin occurred and was resumed once plant conditions were restabilized; i.e., about 5 minutes after the pin was replaced and the feeder brought back on line. Such interruptions were of little real consequence since they typically lasted no more than 10 minutes. Table 3-2 summarizes the shear pin occurrences during sampling at the SNOX.

3.2 Samples Collected

3.2.1 Types and Numbers of Samples

The primary kinds of chemicals measured in various flue gas, solid, and liquid samples from the SNOX process are summarized in Table 3-3. The chemicals measured are shown, along with indications of the sample matrices from which samples were collected. More detail on the sampling and analysis conducted is given in Table 3-4, which shows the constituents measured in samples from the SNOX field effort. In Table 3-4, flue gas locations are distinguished from solid and liquid sampling locations. All locations are numbered as indicated in Figure 2-1 and Table 2-1.

The methods used to collect samples from flue gas streams at the SNOX are summarized in Table 3-5. The sampling methods are described in detail in the QAPP. Size-fractionated particle samples were collected in the Multi-Metals trains. Because of the requirement for both horizontal and vertical sampling at some locations, in-stack cyclones were not used. Glass cyclones with particle diameter cut points of 10 μm and 5 μm were fabricated for this project and were used ahead of the filter in each of these sampling trains at Location 18.

The ducts were not traversed while sampling for anions for two reasons. First, at Locations 18 and 19 only two ports were available for sampling, and the requirements for collecting five types of samples did not allow two trains to be traversing the duct in a single day. Second, the extremely small area available for working at Locations 18, 19, and 21 made traversing with two sampling trains simultaneously very difficult. Therefore the site-specific sampling plan called for single-point, isokinetic sampling to be conducted for anions.

The daily sampling schedule on both organic and inorganic days was essentially the same at all flue gas locations. Thus the numbers of samples collected at each site was nominally the same. The actual numbers of sample runs of various types performed at the SNOX flue gas locations are shown in Table 3-6. Those occurrences and the resulting deviations are described later in this report.

Table 3-7 shows the number of sample collections made each day at the solid and liquid sampling locations. Only a single sample is shown each day for boiler feed coal, representing the daily composite sample provided by Niles staff. Those daily composites in turn were comprised of from 17 to 22 individual portions collected from each of the four feeders every half hour during the sampling day.

3.2.1.1 Flue Gas Samples. Flue gas sampling at the SNOX was nearly identical at the four flue gas locations. The primary exception is that particle size distributions were determined by cascade impactor at the baghouse inlet and outlet (Locations 18 and 19) but not at the other locations. Also, as agreed with DOE, the sampling duration for the Multi-Metals train (Method 29) was extended from 6 hours to 8 hours at Locations 19, 20, and 21, to counteract the low particulate concentrations expected at these locations downstream of the baghouse. As Table 3-4 indicates SVOC, elements, and anions were determined in both gas

and particulate phases in the flue gas streams. For SVOC and elements, the vapor/particle phase distribution was determined. Ammonia and cyanide were measured in the vapor phase only. The particulate filter used with the ammonia and cyanide trains was used for radionuclide and elemental carbon analyses. That filter was used in isokinetic sampling at a single point in the duct using a short sampling probe. As a result, the particulate sample obtained may not be completely representative of the particulate matter at all points in the cross section of the duct. Data sheets from sampling and data reduction calculations are provided in Appendix D.

3.2.1.2 Solid and Liquid Samples. The solid and liquid sample collection at the SNOX process (Table 3-4) was accomplished as follows. Ohio Edison personnel collected samples of feed coal (Location 1) every half hour from each of the four coal feeders on Boiler No. 2, throughout the period of sampling on every sampling day. Ohio Edison staff composited those multiple daily samples on-site to a single daily 3 kg coal sample. Sulfuric acid (Location 22) was collected once each sampling day by ABB personnel, and a single sample of SO₂ catalyst waste (Location 23) was provided for the study by ABB personnel. Battelle staff collected samples of baghouse ash three times each day from each of the three hoppers on one side (i.e., one half) of the baghouse. Baghouse collections were made just before the automated dump times of the hopper, to assure that the hoppers were full at the time of collection.

3.2.2 Compositing Procedures

Solid samples were obtained at the SNOX in multiple collections during each sampling day, as described above. The purpose of this approach was to obtain samples representative of the range of plant operating conditions that occurred during each sampling day. The multiple samples collected at each solid sampling location on each day were then composited into a single daily sample. Portions of the resulting daily composite samples were then distributed to the various analytical laboratories as needed.

The solid samples from SNOX that underwent sample compositing were boiler feed coal (Location 1), and baghouse ash (Location 24). The boiler feed coal samples were

collected and composited on-site by Ohio Edison staff, as described above. The daily feed coal sample was put into two bags, which were then sealed. Commercial Testing and Engineering Company (CTE) of Conneaut, Ohio, took portions of feed coal from both bags for each day to create samples for analysis. Compositing of baghouse ash samples was done by CTE. CTE also broke the composite samples down into portions for the various analytical laboratories. Baghouse ash samples were composited by taking equal quantities of each sample collection over the course of each day.

Battelle prepared a set of instructions, in the form of tables, for the compositing and apportioning of the samples. These instructions are shown in Table 3-8. Each page of Table 3-8 addresses a different type of solid sample, beginning with the boiler feed coal, then baghouse ash. Shown in these tables are the sample identification, dates, and sample apportioning procedures.

During the compositing the system for identifying the samples was altered, and a composite sample ID was established. Those composite ID's are shown in Table 3-9. The date was kept, although in a slightly different format; however, the sampling site number was replaced with a term descriptive of the source of the sample. Examples of the two sets of ID's are shown in Table 3-9.

Solid samples taken on organic days were analyzed for SVOC. Thus only two portion were made from the samples on these days -- one for the SVOC analysis and the other for an archive. On the inorganic days several portions were made from the composites. Analyses for metals were required for the samples taken from both of the sampling sites. These analyses were performed by CTE at its laboratory in Denver (CTE-Denver). Analyses covering ultimate/proximate, moisture, heat, carbon, sulfur, and particle size were performed by the Conneaut laboratory of CTE. Analyses for chlorine, fluorine, phosphates, and sulfates were performed by Battelle's Columbus Operations (BCO). The International Technology (IT) Corporation ran the radiological (RAD) analysis of the samples for gamma-emitting isotopes. Sample portions analyzed by each of these laboratories are indicated in Table 3-8.

3.2.3 Numbers of Analyses

The number and type of analyses conducted on the collected gas, solid, and liquid samples are listed in Table 3-10 according to sample location and sampling method. The number of samples collected is provided for reference and discrepancies between number of samples collected and number of samples analyzed are noted as appropriate.

3.2.4 Problems and Deviations in Sampling

Some problems occurred at the SNOX that made the field sampling more difficult, but in only a few cases did significant deviations from the sampling plan occur. The first problem at the SNOX process was the difficulty in conducting isokinetic traverse sampling at Location 20, the SCR outlet. At this location, the ports arranged horizontally across the duct were all originally fitted with valves of nominal 5-cm (2-inch) inner diameter. Chester Environmental staff had prepared small-diameter sampling probes suitable for such a small port size prior to arrival at the plant. However, in setting up the sampling equipment on July 17, it was found that the actual inner diameter of the valve opening was closer to 1.5 inches. The small-diameter probes could be inserted into the ports with reasonable effort, but could only be withdrawn with great difficulty once the probe sheath had expanded due to the elevated temperature in the duct. Sampling was begun on July 18 with the original valves in place, but proved so difficult and time-consuming that completion of the daily schedule was jeopardized, and several glass sampling nozzles were broken. It became apparent that sampling with the existing valves in place was simply not feasible. As a result, four 7.6-cm (3-inch) full-port valves were borrowed from plant personnel and installed at Location 20. With these valves in place, probe traversing at Location 20 could be done in a normal manner. Specific deviations from the sampling plan that occurred as a result of the initial port problems at Location 20 are noted below.

A second problem occurred at Location 20 on July 19. It was found that the particulate filter used on the Multi-Metals train (Method 29) at Location 20 would clog up completely after only about 1 hour of sampling. Since this location is downstream of the SNOX baghouse, clogging by particulate was not expected, and indeed the filters appeared

clean when removed from the train. However, closer inspection revealed that the filters were covered with a fine white crystalline material. Consultation with ABB staff revealed that excess ammonia, above an ammonia/NO_x stoichiometry of 1.0, was being added to the SCR inlet of the SNOX process. Apparently, the excess ammonia was sufficient to cause formation of ammonium sulfite and/or sulfate salts at the conditions in the duct, and deposits of those materials were rapidly clogging the filters. When ABB staff reduced the ammonia addition to the minimum required, the filter clogging stopped and did not recur. The time spent diagnosing and dealing with the problem delayed completion of sampling at Location 20, but resulting deviations from the sampling plan were minor, as noted below.

The deviations from the sampling plan that resulted from the problems noted above and from delays noted in Section 3.1.3 are as follows:

- (1) Due to the port problems at Location 20, that delayed sampling at Location 20 and required extra attention from Chester Environmental staff, the aldehyde samples from Locations 20 and 21 were not run as planned on July 18. Those samples were made up on July 23 at both locations.
- (2) As a result of the severe filter clogging problems on July 19 at Location 20, completion of the Multi-Metals train and other sampling at that location was delayed. With concurrence from DOE's on-site representative, Battelle's Field Sampling Manager shortened the multi-metals run to 6 hours from the planned 8 hours in order to keep the sampling day to a reasonable length.
- (3) No sampling was conducted at the SNOX on July 20 due to the coal feeder problem noted above.
- (4) Due to the low particulate loadings present at the baghouse outlet (Location 19) the cascade impactor taken on July 19 showed no visible particulate deposits on any impaction stage. Discussions among Battelle and Chester staff and the DOE on-site representative led to the decision to resample at Location

19 using the same stages on successive days. This approach was implemented on July 21-24.

- (5) Flue gas oxygen readings at the furnace outlet were sometimes lower than the nominal acceptable range of 1.8-3.0 percent (see Table 2-3). Discussions with Niles control room staff indicated the plant was operating entirely normally and the percent oxygen readings were acceptable. As a result, the O₂ levels were noted but no change was made in sampling or plant operating conditions. Near the end of the field periods at Niles, Ohio Edison staff reported that recalibration of the Boiler No. 2 outlet O₂ sensor showed that it had been reading about 0.5 percent low. (This correction is made in Table 2-4.) This observation at least partly reconciles the expected and observed O₂ levels.

Another deviation from the sampling plan occurred at Locations 18 and 19. No filters were collected as part of the Method 29 train blanks for these locations. This was an oversight that was not discovered until after the field study. In Section 5 no results are reported for train blanks for these two locations. The train blank at Location 21 was used to correct sample data at all four flue gas locations.

3.3 Mass Flows

Mass flows of particulate matter, ash, and sulfur are presented in this section of the report. Material balances for ash and sulfur are also presented. Mass flows in major streams are presented in Table 3-11 for the three inorganic sampling days. Table 3-12 contains the results for the three organic sampling days.

3.3.1 Ash Material Balances

Using data from the emissions tests on the SNOX system, material balances for ash were performed on the baghouse. Because the data on particulate mass loading at Locations 20 and 21 are believed to reflect artifact ammonia/sulfur compounds and acid mist,

respectively, these data were not used to calculate ash balances. Consequently, material balances for ash were calculated only for the SNOX baghouse. Separate material balances were calculated for each test run, and the average of the three runs was calculated.

3.3.1.1 Assumptions. In performing these calculations, the following assumptions were made:

General:

- It was assumed that the coal fired during each day of the test was of uniform composition.
- It was assumed that the boiler was operating at constant conditions. This assumption is supported by the plant process data which verify that the plant operated at as nearly constant conditions as practical.
- It was assumed that samples collected at any time were representative of the process streams at all times. Thus, only one metals/particulate sample was collected each test day, and these samples were assumed to be representative of conditions throughout the day. Considering the fact that some samples required 8-hour sampling periods and others required only a few minutes to collect sufficient matter for analysis, this assumption was necessary.

SNOX System:

- The SNOX process system provides no practical means for measuring the flow of material exiting the baghouse as collected ash. Knowing that the material flow into and out of the baghouse must be in balance, it was assumed that the total flow rate of the material from the baghouse hoppers was equal to the difference between (1) the particulate entering the baghouse with the flue gas and (2) the particulate exiting the baghouse with the flue gas.

- The SNOX process system provides no practical means for measuring the rate at which acid is produced in the SO₂ condenser. Knowing that the sulfur flow into and out of the SNOX system must be in balance, the rate of acid production was estimated by performing a sulfur balance on the SNOX system and by adjusting the calculated value for the concentration of acid based on ABB experience.
- Several of the flue gas sampling locations were less than ideal, e.g., the sampling location was less than one stack diameter downstream of a 90° Turn in the gas flow path. Probably as a result of this, the flow rates at Locations 18, 19, 20, and 21 did not agree. Thus, for ash mass balances, it was assumed that the flow rate at the most ideal sampling location (Location 18) was correct and flow rates at the other locations were estimated by considering the excess O₂ level and, in the case of Location 21, flue gas generated by the second support burner.
- The SNOX process system produces a small quantity of SCR reactor waste that is removed during reactor cleaning, about once each year. Based on ABB experience, the rate of generation of this waste is about 0.25 lb/hr. Although a sample of this waste was collected and analyzed, it was not included in the mass balance calculations because, to properly account for it, one would also have to account for the SCR reactor material installed in and removed from the reactor during periodic (maybe every few years) catalyst changes. In any case, the low rate at which this material is produced would have resulted in it having no impact on the mass balance calculations.

3.3.1.2 Ash Material Balance Calculations. Tables 3-13 through 3-15 show the material balance calculations for the three inorganic test days. The comments column for each table gives details regarding the calculations.

Tables 3-13a and 3-13b show the particulate emissions calculations. While making the calculations reported in this section it was noted that the flow rates for the various

sampling points on the SNOX system were not in agreement. This was attributed to the poor sampling conditions at Locations 19, 20, and 21; the flow measurements at those locations are suspect. Thus, the particulate emissions calculations were done in two ways, first with the measured flow rates (Table 3-13a) and then with adjusted flow rates (Table 3-13b). The adjustments were made by assuming that the flow rates measured at Location 18 were most likely to be correct (this Location had the best sampling conditions), and calculating flow at Locations 19, 20, and 21 based on the oxygen values measured at those locations and, in the case of Location 21, including the effect of the auxiliary burner located between Location 20 and Location 21. Results calculated in Table 3-13b were used as input to the overall ash mass balance calculation shown in Table 3-15. The adjusted flow rates were also used for all metals mass balances and emission factor calculations.

Table 3-14 shows the calculations used to determine the acid production rate for the SNOx system. Table 3-15 shows the mass balance calculations for ash for the three metals test runs. As mentioned earlier, calculations are only shown for the mass balance across the baghouse. The generation rate of baghouse catch obtained from the ash mass balance calculations shown in this table served as input for the metal mass balance calculations shown in Table 6-1.

3.3.1.3 Ash Material Balance Results. Table 3-16 shows the material balance results for ash. The nature of the assumptions that were made in performing the ash balance calculations (i.e., perfect closure for particulate mass) essentially forced the ash balances to show near perfect closure for the baghouse, as can be seen from the calculations reported in Table 3-15. These assumptions were necessary because it was not possible to measure the baghouse catch mass flow rate, and the mass flow rate was calculated by differences between the mass flow rates that were measured. Thus, the near perfect closure for the ash material balances does not confirm the quality of the emissions tests.

Note in Table 3-15 that the fraction of carbon in the samples of particulate matter (lines 7, 11, and 15) was subtracted from particulate levels (lines 8, 12, and 16) to determine the ash levels. The average level of carbon in the particulate matter is reported in Section 5.8 as 3.0 percent for particulate matter in flue gas entering the SNOX baghouse at Location 18, 0.03 percent for particulate matter in the flue gas exiting the baghouse (Location 19),

and 8.1 percent in the baghouse catch (Location 24). These results are believed to be accurate for the collected samples. The difference between the carbon content of the Location 18 and Location 24 samples may be attributable to poor sampling conditions for large particles in the horizontal duct before the baghouse. Large particles with relatively high carbon content may have been concentrated near the bottom of the duct due to sedimentation and been caught by the baghouse but not sampled representatively in the flue gas. This situation was more severe the following week when Battelle sampled the boiler effluent with the SNOX process shut down (see Battelle's report on "A Study of Toxic Emissions from a Coal-Fired Power Plant--Niles Station Boiler No. 2"). For that study, the carbon content of particulate matter entering the electrostatic precipitator (ESP) was 4.3 percent; the flue gas exiting the ESP had an average carbon content of 0.1 percent; and the ESP catch in hopper rows 1, 2, 3, and 5 had a carbon content of 79, 15, 5.9 and 1.9 percent, respectively. In that study, a layer of ash was observed resting on the bottom of the duct at the ESP inlet. To the extent that particles in the flue gas entering the baghouse were similarly not collected representatively because of sedimentation, the bias in the carbon content may have affected the ash material balance.

3.3.2 Sulfur Material Balances

Using the data produced by the emissions tests on the SNOX system, sulfur material balances were performed on the overall SNOX system. Separate material balances were calculated for each test run, and the average of the three runs was calculated.

3.3.2.1 Assumptions. The assumptions necessary for making the sulfur material balances were identical to those required for the ash material balances (Section 3.3.1).

3.3.2.2 Sulfur Material Balance Calculations. Table 3-17 shows the material balance calculations for sulfur for the three days on which sampling was conducted for inorganic substances. The comments column for each table gives details regarding the calculations.

3.3.2.3 Sulfur Material Balance Results. Table 3-18 shows the material balance results for sulfur. The nature of the assumptions that were made in performing the sulfur balance calculations essentially forced the sulfur balance to show near perfect closure for the SNOX system, as can be seen from the calculations reported in Table 3-17. These assumptions were necessary because it was not possible to measure the production rate of acid, and the acid production rate was calculated by differences between the SO₂ flow rates in and out of the SNOx system. However, the calculated acid production rate was consistent with plant experience of about 1,800 lb/hr. Thus, although the near perfect closure for sulfur mass balances does not say anything regarding the quality of the emissions tests, the agreement of the calculated acid production rate and plant experience is encouraging.

TABLE 3-1. OVERALL SCHEDULE OF ACTIVITIES

Date	Activity
July 15, 1993	Personnel and equipment arrived at site, initial meeting and check-in
July 16-17	Equipment set up at SNOX locations; field site preparations
July 18-19	Sampling at SNOX
July 20	Down day due to failure of coal feeder
July 21-24	Completion of sampling at SNOX

TABLE 3-2. SUMMARY OF COAL FEEDER SHEAR PIN INTERRUPTIONS

Date	Feeder No.	Shear Pin Out Times	
		Start	Stop
7/18/93	2	0950	0957
		1300	1305
		1334	1337
		1407	1420
7/19/93	2	0740	0744
7/24/93	4	0700	0705

TABLE 3-3. SUBSTANCES MEASURED IN SAMPLES

<u>Organic Chemicals</u>	
Semivolatile Organic Compounds (SVOC)	
Polynuclear Aromatic Hydrocarbons (PAHs)	19 compounds (flue gas and solid samples)
Other SVOC	11 compounds (flue gas and solid samples)
Volatile Organic Compounds	41 compounds (flue gas samples by canister)
	36 compounds (flue gas samples by VOST)
Aldehydes	4 compounds (flue gas samples)
<u>Inorganic Substances</u>	
Trace elements (vapor phase)	As, Se, Hg (flue gas samples)
Trace elements	As, Se, Hg, Cd, Cr, Mo, B, Sb, Ba, Be, Pb, Mn, Ni, V, Cu, Co (all samples)
Major elements	Al, K, Ti, Si, Na (all samples)
Anions	Cl ⁻ , F ⁻ , PO ₄ ⁼ , SO ₄ ⁼ (flue gas, solid and liquid samples)
Other substances	NH ₃ , CN ⁻ (flue gas samples)
Elemental carbon	(flue gas, boiler feed coal, and baghouse ash samples)
Radionuclides (solid phase)	U ²³⁴ , U ²³⁵ , Th ²²⁹ , Th ²³⁰ , Th ²³⁴ , Ra ²²⁶ , Ra ²²⁸ , Pb ²¹⁰ , Pb ²¹¹ , Pb ²¹² (flue gas, boiler feed coal, and baghouse ash samples)

TABLE 3-4. IDENTIFICATION OF SUBSTANCES MEASURED
IN PROCESS STREAMS

Substance	Sampling Location							
	Solid/Liquid				Flue Gas			
	1	22	23	24	18	19	20	21
PAH/SVOC				•	•	•	•	•
VOC					•	•	•	•
Aldehydes					•	•	•	•
Elements Vapor Solid/Liquid	•	•	•	•	• •	• •	• •	• •
Anions Vapor Solid/Liquid	•	•		•	• •	• •	• •	• •
Cyanide					•	•	•	•
Ammonia					•	•	•	•
Carbon				•	•	•	•	•
Radionuclides	•			•	•	•	•	•
Particle Mass					•	•	•	•
Particle Size Distribution				•	•	•		
Ultimate/Proximate	•							

TABLE 3-5. FLUE GAS SAMPLING METHODS

Substance	Sampling Method ^(a)
SVOC	Modified Method 5 (Method 23)(i,t)
VOC	Summa Canister from Modified Method 5 Train Volatile Organic Sampling Train (VOST)
Aldehydes	TO-5, Impingers
Elements	Multi-Metals Train (Method 29) for Vapor and Particulate (i,t) HEST Carbon-impregnated Filter for Vapor Only
Anions	Method 26A (Modified) (i)
Ammonia	APHA 401 - Impinger (i)
Cyanide	APHA 808 - Impinger (i)
Carbon	Filter on Ammonia and Cyanide Trains (i)
Radionuclides	Filter on Ammonia and Cyanide Trains (i)
Particle Mass	Cyclones and Filter on Multi-Metals Trains (i,t)
Particle Size Distribution	Cascade Impactors (i) (Locations 18, 19 only)

(a) Characteristics of methods indicated in parentheses: i = isokinetic, t = traversing.

TABLE 3-6. NUMBER OF SAMPLING RUNS AT FLUE
GAS SAMPLING LOCATIONS

Run Type	Location			
	18	19	20	21
Organic				
Modified Method 5 (SVOC)	3	3	3	3
Canisters ^(a) (VOC)	9	9	9	9
VOST ^(a) (VOC)	9	9	12 ^(b)	9
TO-5 (aldehydes)	3	3	3	3
Inorganic				
Multi-Metals Train	3	3	3	3
HEST Sampler	3	3	3	3
Method 26A (anions)	3	3	3	3
APHA 401 (ammonia)	3	3	3	3
APHA 808 (cyanide)	3	3	3	3
NH ₃ /CN ⁻ Filter (carbon)	3	3	3	3
NH ₃ /CN ⁻ Filter (radionuclides)	3	3	3	3
Impactors (particle size distribution)	3	1 ^(c)		

- (a) Each canister run used three canisters; each VOST run used three sets of VOST cartridges.
- (b) Includes VOST audit run on July 20, 1993.
- (c) Same impactor stages run repeatedly to obtain sufficient sample.

TABLE 3-7. NUMBER OF SAMPLES COLLECTED FROM SOLID AND LIQUID PROCESS STREAMS

Location #	Date					
	7/18/93	7/19/93	7/21/93	7/22/93	7/23/93	7/24/93
1 Boiler Feed Coal	1	1	1	1	1	1
24 Baghouse Ash	3	3	3	3	3	3
22 Sulfuric Acid	1	1	1	1	1	1
23 SO ₂ Catalyst Waste	0	0	0	0	1	0

TABLE 3-8. SAMPLE COMPOSITING AND SPLITTING SCHEDULE (BY DAY)

BOILER FEED COAL								
Sample #	Bag Number	Matrix	Sample Date	Compositing Instructions	Composite ID	Splits	Minimum Split Wt.	Analyzing Laboratory
N-1-PRS-718	1	BOFEED	Jul 18, 1993	Equal amounts from each sample	JL1893BOFED	Archive		BCO
	2	ORG						
N-1-PRS-719	1	BOFEED	Jul 19, 1993	Equal amounts from each sample	JL1993BOFED	Metals	20 g	EA
	2	INORG				ULTI/PROX.	200 g	CTE
						MOIST.HEAT		
						CL/F/PO4	20 g	BCO
						RAD	1300 g	IT
						Be,B	60 g	CTE-Denver
						Archive		BCO
N-1-PRS-721	1	BOFEED	Jul 21, 1993	Equal amounts from each sample	JL2193BOFED	Archive		BCO
	2	ORG						
N-1-PRS-722	1	BOFEED	Jul 22, 1993	Equal amounts from each sample	JL2293BOFED	Metals	20 g	EA
	2	INORG				ULTI/PROX.	200 g	CTE
						MOIST.HEAT		
						CL/F/PO4	20 g	BCO
						RAD	1300 g	IT
						Be,B	60 g	CTE-Denver
						Archive		BCO
N-1-PRS-723	1	BOFEED	Jul 23, 1993	Equal amounts from each sample	JL2393BOFED	Archive		BCO
	2	ORG						
N-1-PRS-724	1	BOFEED	Jul 24, 1993	Equal amounts from each sample	JL2493BOFED	Metals	20 g	EA
	2	INORG				ULTI/PROX.	200 g	CTE
						MOIST.HEAT		
						CL/F/PO4	20 g	BCO
						RAD	1300 g	IT
						Be,B	50 g	CTE-Denver
						Archive		BCO

Acronyms and Abbreviations used in Table 3-8:

Archive - remainder of sample after compositing and aliquotting have been done; B - analysis for boron; BAGHOUSE or BAGH - sample of ash from baghouse; Be - analysis for beryllium; BOFED and BOFEED - boiler feed coal sample; C - analysis for carbon; CL/F/PO₄(SO₄) - analysis for chloride, fluoride, phosphate (and sulfate); HEAT - analysis of coal for Btu/lb; INORG - inorganic sampling day; JL - July; Metals - analyses for major and trace elements; MOIST - moisture analysis; ORG - organic sampling day; Particle Size Distribution - analysis of sample for particle size distribution; PRS - process solid sample; RAD - radiological analysis by gamma scan; SVOC - analysis for semivolatile organic compounds; ULTI/PROX - ultimate/proximate analysis.

TABLE 3-8. (Continued)

BAGHOUSE ASH								
Sample #	Hopper/ Time	Matrix	Sample Date	Compositing Instructions	Composite ID	Splits	Minimum Split Wt.	Analyzing Laboratory
N-24-PRS-718	1/830	BAGHOUSE	Jul 18, 1993		JL1893BAGH	SVOC	20 g	BCO
	1/1230					Archive		BCO
	1/1630	ORG						
	2/830							
	2/1230							
	2/1630							
	3/830							
	3/1230							
	3/1630							
N-24-PRS-719	1/830	BAGHOUSE	Jul 19, 1993		JL1993BAGH	Metals	20 g	CTE-Denver
	1/1230					RAD	600 g	IT
	1/1630	INORG				C	25 g	CTE
	2/830					F/CL/PO4/SO4	25 g	BCO
	2/1230					Archive		BCO
	2/1630					Particle Size Dist.	200 g	CTE
	3/830							
	3/1230							
	3/1630							
N-24-PRS-721	1/1230	BAGHOUSE	Jul 21, 1993		JL2193BAGH	SVOC	20 g	BCO
	1/1630					Archive		BCO
	1/1940	ORG						
	2/1230							
	2/1630							
	2/1940							
	3/1230							
	3/1630							
	3/1940							
N-24-PRS-722	1/830	BAGHOUSE	Jul 24, 1993		JL2493BAGH	Metals	20 g	CTE-Denver
	1/1230					RAD	600 g	IT
	1/1630	INORG				C	25 g	CTE
	2/830					F/CL/PO4/SO4	25 g	BCO
	2/1230					Archive		BCO
	2/1630					Particle Size Dist.	200 g	CTE
	3/830							
	3/1230							
	3/1630							
N-24-PRS-723	1/830	BAGHOUSE	Jul 23, 1993		JL2393BAGH	SVOC	20 g	BCO
	1/1230					Archive		BCO
	1/1630	ORG						
	2/830							
	2/1230							
	2/1630							
	3/830							
	3/1230							
	3/1630							
N-24-PRS-724	1/830	BAGHOUSE	Jul 24, 1993		JL2493BAGH	Metals	20 g	CTE-Denver
	1/1230					RAD	600 g	IT
	1/1630	INORG				C	25 g	CTE
	2/830					F/CL/PO4/SO4	25 g	BCO
	2/1230					Archive		BCO
	2/1630					Particle Size Dist.	200 g	CTE
	3/830							
	3/1230							
	3/1630							

TABLE 3-9. EXAMPLES OF SAMPLE AND COMPOSITE ID'S

Description of Sample	Example of Sample ID	Composite ID Made Up Of The Corresponding Samples
Boiler Feed Coal	N-1-PRS-719	JL 19 93 BOFED
Baghouse Ash	N-24-PRS-719	JL 19 93 BAGH

TABLE 3-10. NUMBER OF ANALYSES CONDUCTED

NILES STATION - SNOX NUMBER OF GAS SAMPLES TO BE ANALYZED***** (10/7/93)																			
NUMBER OF ANALYSES																			
Sampling Location	Description	Sampling Technique	Number Samples Collected	VOC- Summa	VOC- VOST	VOC- Liquid	Aldehydes#	Gas/Solid SVOC	Liquid SVOC	Dioxin/Furans	Volatile As, Hg, Se Elemental##	NH ₃	C/F	PO ₄	SO ₄	Cu	Rad C	Mass Loading	PSD UIU/Prox
18	Baghouse Inlet	Summa**	9	9															
		Aldehyde train	3				9	6											
		Method 23 train	3																
		HEST	3																
		Method 29 train	3																
		NH ₃ train	3																
		Cu train	3																
		Method 26A train	3																
		VOST*****	9		9														
		Cyclones (M29)	3																
19	Baghouse Outlet	Summa**	9	9															
		Aldehyde train	3				9	6											
		Method 23 train	3																
		HEST	3																
		Method 29 train	3																
		NH ₃ train	3																
		Cu train	3																
		Method 26A train	3																
		VOST*****	9		9														
		Inspectors	1																
20	SCR Reactor Outlet	Summa**	9	9															
		Aldehyde train	3				9	6											
		Method 23 train	3																
		HEST	3																
		Method 29 train	3																
		NH ₃ train	3																
		Cu train	3																
		Method 26A train	3																
		VOST*****	9		9														
		Inspectors	1																
21	SNOX Tower Outlet	Summa**	9	9															
		Aldehyde train	3				9	6											
		Method 23 train	3																
		HEST	3																
		Method 29 train	3																
		NH ₃ train	3																
		Cu train	3																
		Method 26A train	3																
		VOST*****	9		9														
		Inspectors	1																

***Three Summa canisters were collected in each of three runs for a total of 9 samples.

****Single filter from both NH₃ and CN trains analyzed for nitrobenzenes and carbon.

*****Numbers include entrained fly ash; exclude QA/QC samples.

*****Three VOST samples were collected in each run; each VOST sample consists of two cartridges.

Each aldehyde train sample provides 3 components for analysis.

Method 29 train provides 2 components; front half (excluding filter and cyclones) and back half (excluding filter and cyclones) for Hg analysis.

Number reflects element (excluding Hg) analyses.

Total number of gas sample analyses at Niles-SNOX

***Three Summa collectors were collected in each of three runs for a total of 9 samples.
 ****Single filter from both NH₃ and Cu trains analyzed for nitrobenzenes and carbon.
 *****Numbers include entrained fly ash; exclude QA/QC samples.
 *****Three VOST samples were collected in each run; each VOST sample consists of two cartridges.
 #Each aldehyde train sample provides 3 components for analysis.
 ## Method 29 train provides 2 components; front half (excluding filter and cyclones) and back half for element (excluding Hg analysis and cyclones) for Hg analysis.
 Number reflects element (excluding Hg) analyses.

Total number of gas sample analyses at Niles-SNOX

TABLE 3-10. (Continued)

NUMBER OF ANALYSES																					
NILES-SNOX NUMBER OF PROCESS SAMPLES TO BE ANALYZED (10/7/93)		Number Samples Collected	VOC- Summa	VOC- VOST	VOC- Liquid	Aldehydes#	Gas/Solid SVOC	Liquid SVOC	Dioxins/ Furans	Volatile As, Hg, Se	Elements##	NH ₄	Cl/F	PO ₄	SO ₄	Cn	Rad	C	Mass Loading	PSD	Urb/Prox
1	Boiler Feed (Solid)	37									3		3	3			3				3
22	Sulfuric Acid (Liquid)	3									3			3	3						
23	SO ₂ Catalyst Waste (Solid)	1									1										
24	Baghouse Ash (Solid)	37					3				3	3	3	3	3	3	3				3
#Number of composite samples to be generated.																					
##Element analysis for liquid samples (excluding sulfuric acid) includes dissolved (filtrate) and total (unfiltered) analyses.																					
TOTAL NUMBER OF PROCESS SAMPLE ANALYSES FOR NILES-SNOX		0	0	0	0	0	3	0	0	0	10	0	6	9	6	0	6	3	0	3	3
TOTAL NUMBER OF GAS AND PROCESS SAMPLE ANALYSES FOR NILES-SNOX		36	36	0	36	36	27	0	0	12	43	12	30	21	18	12	18	15	9	7	3

TABLE 3-11. MAJOR STREAM FLOWS FOR INORGANIC DAYS

Stream	Units	Date		
		July 19	July 22	July 24
Coal Feed	lb/hr	91,700	92,200	90,600
	kg/hr	41,600	41,800	41,100
Fraction of Flue Gas to SNOX ^(a)	percent	28.2	28.7	29.6
Flue Gas				
Baghouse Inlet ^(b)	Nm ³ /min	1,801	1,767	1,748
Baghouse Outlet ^(c)	Nm ³ /min	1,801	1,818	1,898
SCR Outlet ^(c)	Nm ³ /min	2,004	2,047	2,077
Condenser Outlet ^(c)	Nm ³ /min	2,099	2,142	2,489
Particulate Matter ^(d)				
Baghouse Inlet	lb/hr	492	459	523
	kg/hr	223	208	237
Baghouse Outlet	lb/hr	0.6	1.4	9.3
	kg/hr	0.3	0.63	4.2
SCR Outlet ^(e)		NR	NR	NR
Condenser Outlet ^(f)	lb/hr	13.9	7.7	13.1
	kg/hr	6.3	3.5	5.9
Baghouse Catch ^(g)	lb/hr	491	457	514
	kg/hr	223	207	233
Acid Production ^(h)	lb/hr	2,210	2,021	2,118
	kg/hr	1,002	917	961

(a) Calculated from flue gas generated by coal combustion and flue gas flow rate measured at Location 18.

(b) At stack oxygen level.

(c) Calculated from flue gas flow rate at Location 18 and oxygen levels at the specific location.

(d) Based upon calculated flue gas flow and measured particulate loading.

(e) Not reported because measured particulate mass loadings are believed to be artifacts (see Table 2-2).

(f) These values may be indicative of sulfuric acid mist (see Table 2-2).

(g) By difference in particle mass flow across the baghouse.

(h) Calculated from decrease in SO₂ across the SNOX system.

TABLE 3-12. MAJOR STREAM FLOWS FOR ORGANIC DAYS

Stream	Units	Date		
		July 18	July 21	July 23
Coal Feed	lb/hr	93,200	91,000	90,800
	kg/hr	42,300	41,300	41,200
Fraction of Flue Gas to SNOX ^(a)	percent	28.3	28.7	30.7
Flue Gas				
Baghouse Inlet ^(b)	Nm ³ /min	1,950	1,986	1,926
Baghouse Outlet ^(c)	Nm ³ /min	1,902	1,831	1,913
SCR Outlet ^(c)	Nm ³ /min	2,047	2,095	2,301
Condenser Outlet ^(c)	Nm ³ /min	2,013	2,266	2,113

(a) Calculated from flue gas generated by coal combustion and flue gas flow rate measured at Location 18.

(b) At stack oxygen level.

(c) Calculated from flue gas flow rate at Location 18 and oxygen levels at the specific location.

**TABLE 3-13a. EMISSION CALCULATIONS FOR PARTICULATE MATTER USING MEASURED FLUE GAS FLOW RATES
AT EACH LOCATION**

Particulate Emissions: Metals Runs

Test Date	M-1 7/19/93	M-2 7/22/93	M-3 7/24/93	Average	Comments
SNOx Inlet (Location 18)					
1. Gas flow rate, dry	Ncm/min				From sampling calculations (Appendix D-10)
2. Particulate loading	mg/Ncm	1767.00	1748.00		From sampling calculations (Appendix D-10)
3a. Particulate emissions	kg/hr	2063.50	2262.30		#2*#1*60/(1000000)
3b. Particulate emissions	lb/hr	222.98	237.27		#3a*2.205
		491.67	523.18		
Baghouse Outlet (Location 19)					
4. Gas flow rate, dry	Ncm/min				From sampling calculations (Appendix D-10)
5. Particulate loading	mg/Ncm	1589.00	1582.00		From sampling calculations (Appendix D-10)
6a. Particulate emissions	kg/hr	2.70	37.20		#5*#4*60/(1000000)
6b. Particulate emissions	lb/hr	0.26	3.53		#6a*2.205
		0.58	7.79		
SO2 Reactor Inlet (Location 20)					
7. Gas flow rate, dry	Ncm/min				From sampling calculations (Appendix D-10)
8. Particulate loading	mg/Ncm	3905.00	3617.00		From sampling calculations (Appendix D-10)
9a. Particulate emissions	kg/hr	291.00	298.70		#8*#7*60/(1000000)
9b. Particulate emissions	lb/hr	53.57	64.82		#9a*2.205
		118.12	142.94		
SNOx Outlet (Location 21)					
10. Gas flow rate, dry	Ncm/min				From sampling calculations (Appendix D-10)
11. Particulate loading	mg/Ncm	1706.00	1952.00		From sampling calculations (Appendix D-10)
12a. Particulate emissions	kg/hr	49.90	39.90		#11*#10*60/(1000000)
12b. Particulate emissions	lb/hr	6.10	4.67		#12a*2.205
		13.44	10.30		
Coal Firing Rate					
13. Equivalent firing rate	lb/hr	25827.80	26803.34	26354.86	From Table 2-4 and gas fraction
14. Coal heating value	Btu/lb	12249.00	12306.00	12257.67	From Table 5-52
15a. Firing rate	10 ⁶ Btu/hr	316.36	329.84		#13*#14/1000000
15b. Firing rate	MJ/hr	333764.84	340726.64	347983.15	#15a*1055
Ash Emission Factors					
Boiler emissions (Location 18)					
16a. Ash emissions	kg/hr	222.98	222.98	222.98	#3a

TABLE 3 – 13a. (Continued)

16b. Ash emissions	lb/hr	491.67	491.67	491.67	#3b (#16a/#15b)*1000 #16b/#15a
17a. Ash emissions factor	g/MJ	0.67	0.65	0.64	
17b. Ash emissions factor	lb/10 ⁶ Btu	1.55	1.52	1.49	
Baghouse emissions (Location 19)					
18a. Ash emissions	kg/hr	0.26	0.54	3.53	#6a
18b. Ash emissions	lb/hr	0.58	1.20	7.79	#6b
19a. Ash emissions factor	g/MJ	0.00	0.00	0.01	(#18a/#15b)*1000
19b. Ash emissions factor	lb/10 ⁶ Btu	0.00	0.00	0.02	#18b/#15a
SCR Reactor emissions (Location 20)					
20a. Ash emissions	kg/hr	53.57	48.24	64.82	#9a
20b. Ash emissions	lb/hr	118.12	106.37	142.94	#9b
21a. Ash emissions factor	g/MJ	0.16	0.14	0.19	(#20a/#15b)*1000
21b. Ash emissions factor	lb/10 ⁶ Btu	0.37	0.33	0.43	#20b/#15a
SN/Ox emissions (Location 21)					
22a. Ash emissions	kg/hr	6.10	2.78	4.67	#12a
22b. Ash emissions	lb/hr	13.44	6.14	10.30	#12b
23a. Ash emissions factor	g/MJ	0.02	0.01	0.01	(#22a/#15b)*1000
23b. Ash emissions factor	lb/10 ⁶ Btu	0.04	0.02	0.03	#22b/#15a
Removal Efficiencies					
24. Baghouse	percent	99.88	99.76	98.42	(#17b-#19b)*100/#17b
25. Baghouse & SCR reactor	percent	75.98	78.36	70.93	(#17b-#21b)*100/#17b
26. Total SN/Ox system	percent	97.27	98.75	97.90	(#17b-#23b)*100/#17b

TABLE 3-13b. EMISSION CALCULATIONS FOR PARTICULATE MATTER USING THE FLUE GAS FLOW RATE
AT THE BAGHOUSE INLET, ADJUSTED FOR AIR LEAKAGE AND SUPPORT BURNER FLOW,
FOR ALL LOCATIONS

Particulate Emissions: Metals Runs
Equivalent flows based on Location 18

Test Date	M-1 7/19/93	M-2 7/22/93	M-3 7/24/93	
SNOx Inlet (Location 18)				
1. Gas flow rate, dry	Ncm/min	1767.00	1748.00	From sampling calculations (Appendix D-10)
2. Particulate loading	mg/Ncm	1961.40	2262.30	From sampling calculations (Appendix D-10)
3a. Particulate emissions	kg/hr	207.95	237.27	#2*#1*60/(1000000)
3b. Particulate emissions	lb/hr	491.67	523.18	#3a*2.205
Baghouse Outlet (Location 19)				
4. Gas flow rate, dry	Ncm/min	1818.01	1897.90	Calculated from flow meas. at Loc. 18 and O2 at Loc. 19
5. Particulate loading	mg/Ncm	5.70	37.20	From sampling calculations (Appendix D-10)
6a. Particulate emissions	kg/hr	0.62	4.24	#5*#4*60/(1000000)
6b. Particulate emissions	lb/hr	1.37	9.34	#6a*2.205
SO2 Reactor Inlet (Location 20)				
7. Gas flow rate, dry	Ncm/min	2047.30	2077.24	Calculated from flow meas. at Loc. 18 and O2 at Loc. 20
8. Particulate loading	mg/Ncm	205.90	298.70	From sampling calculations (Appendix D-10)
9a. Particulate emissions	kg/hr	25.29	37.23	#8*#7*60/(1000000)
9b. Particulate emissions	lb/hr	55.77	82.09	#9a*2.205
SNOx Outlet (Location 21)				
10. Gas flow rate, dry	Ncm/min	2142.00	2489.39	Calculated from flow meas. at Loc. 18 and O2 at Loc. 21
11. Particulate loading	mg/Ncm	27.20	39.90	From sampling calculations (Appendix D-10)
12a. Particulate emissions	kg/hr	6.28	5.96	#11*#10*60/(1000000)
12b. Particulate emissions	lb/hr	13.85	13.14	#12a*2.205
Coal Firing Rate				
13. Coal feed rate (Loc. 1)	lb/hr	26433.43	26803.34	From Table 2-4 and gas fraction
14. Coal heating value (Loc. 1)	Btu/lb	12218.00	12306.00	From Table 5-52
15a. Firing rate	10 ⁶ Btu/h	316.36	329.84	#13*#14/1000000
15b. Firing rate	MM/h	333764.84	340726.64	#15a*1055

TABLE 3 – 13b. (Continued)

Particulate Emission Factors					
Boiler emissions (Location 18)					
16a. Particulate emissions	kg/hr	222.98	207.95	237.27	#3a
16b. Particulate emissions	lb/hr	491.67	458.52	523.18	#3b
17a. Particulate emission factors	g/MJ	0.67	0.61	0.68	(#16a/#15b)*1000
17b. Particulate emission factors	lb/10 ⁶ Btu	1.55	1.42	1.59	#16b/#15a
Baghouse emissions (Location 19)					
18a. Particulate emissions	kg/hr	0.29	0.62	4.24	#6a
18b. Particulate emissions	lb/hr	0.64	1.37	9.34	#6b
19a. Particulate emission factors	g/MJ	0.00	0.00	0.01	(#18a/#15b)*1000
19b. Particulate emission factors	lb/10 ⁶ Btu	0.00	0.00	0.03	#18b/#15a
SCR Reactor emissions (Location 20)					
20a. Particulate emissions	kg/hr	34.99	25.29	37.23	#9a
20b. Particulate emissions	lb/hr	77.15	55.77	82.09	#9b
21a. Particulate emission factors	g/MJ	0.10	0.07	0.11	(#20a/#15b)*1000
21b. Particulate emission factors	lb/10 ⁶ Btu	0.24	0.17	0.25	#20b/#15a
SN₀x emissions (Location 21)					
22a. Particulate emissions	kg/hr	6.28	3.50	5.96	#12a
22b. Particulate emissions	lb/hr	13.85	7.71	13.14	#12b
23a. Particulate emission factors	g/MJ	0.02	0.01	0.02	(#22a/#15b)*1000
23b. Particulate emission factors	lb/10 ⁶ Btu	0.04	0.02	0.04	#22b/#15a
Removal Efficiencies					
24. Baghouse	percent	99.87	99.70	98.21	(#17b-#19b)*100/#17b
25. Baghouse & SCR reactor	percent	84.31	87.84	84.31	(#17b-#21b)*100/#17b
26. Total SN ₀ x system	percent	97.18	98.32	97.49	(#17b-#23b)*100/#17b

TABLE 3-14. CALCULATION OF ACID PRODUCTION RATE

Sulfur Balance on SNOx System

Test Date	M-1 7/19/93	M-2 7/22/93	M-3 7/24/93	Average	
Gas flow into SNOx (Location 18)					
1. SO2 into SNOx	2086.00	1936.00	2061.00		From Table 2-5
2. Flue gas into SNOx, dry	1801.00	1767.00	1748.00		From Table 3-13b
3. Flue gas into SNOx, dry	63600.51	62399.84	61728.87		#2*35.314
4. SO2 into SNOx	132.67	120.81	127.22		#3*#1/1000000
5. SO2 into SNOx	1422.61	1295.39	1364.20	1360.73	#4*60°.08062°(64.064/28.9)
Gas flow exiting SNOx (Location 21)					
6. SO2 exiting SNOx	83.00	67.00	68.00		From Table 2-5
7. Flue gas exiting SNOx, dry	2098.65	2142.00	2489.39		From Table 3-13b
8. Flue gas exiting SNOx, dry	74111.76	75642.54	87910.38		#7*35.314
9. SO2 exiting SNOx	6.15	5.07	5.98		#8*#6/1000000
10. SO2 exiting SNOx	65.96	54.34	64.10	61.47	#9*60°.08062°(64.064/28.9)
SO2 balance for SNOx					
11. SO2 into SNOx	1422.61	1295.39	1364.20		#5
12. SO2 exiting SNOx	65.96	54.34	64.10		#10
13. SO2 removed in SNOx	1356.65	1241.04	1300.10		#11-#12
14. SO2 removed in SNOx	95.36	95.80	95.30	95.49	(#11-#12)*100/#11
Acid leaving SNOx					
15. SO2 removed in SNOx	1356.65	1241.04	1300.10		#13
16. SO2, as SO3	1695.49	1551.01	1624.81		#15°(80.06/64.06)
17. SO2, as H2SO4	2077.12	1900.11	1990.53		#15°(98.08/64.06)
18. 94 percent acid	2209.70	2021.40	2117.58	2116.23	#17/94
Moisture Balance on SNOx					
Location 18					
19. Flue gas, dry	1801.00	1767.00	1748.00		From Table 3-13b
20. Flue gas, dry	63600.51	62399.84	61728.87		#19*35.314
21. Moisture	10.76	9.21	8.90		From sampling calculations (Appendix D-10)
22. Moisture	7668.55	6330.02	6030.59		(#21*#20)/(100-#21)
23. Moisture	23124.26	19087.97	18185.05		#22*60°.08062°(18.016/28.9)

TABLE 3-14. (Continued)

TABLE 3-15. ASH MATERIAL BALANCE CALCULATION

Ash Mass Balances for Niles SNOx Test

Test Date	M-1 7/19/93	M-2 7/22/93	M-3 7/24/93	Average	Comments
Boiler Furnace					
1. Coal feed	91730.00 lb/hr	92240.00	90630.00	91533.33	From Table 2-4
2. Moisture in feed coal	6.15 percent	5.97	5.63		From Table 5-52
3. Coal feed, dry	86088.61 lb/hr	86733.27	85527.53	86116.47	#1*((100-#2)/100)
4. Ash in feed coal, dry basis	11.70 percent	11.56	11.51		From Table 5-52
5. Ash in feed coal	10072.37 lb/hr	10026.37	9844.22	9980.98	#3*(#4/100)
Baghouse					
6. Baghouse inlet particulate	491.67 lb/hr	458.52	523.18	491.13	From Table 3-13b
7. Comb. carbon in baghouse inlet	4.70 percent	2.80	1.61		From Table 5-50
8. Ash in baghouse inlet	95.30 percent	97.20	98.39		100-#7
9. Ash in baghouse inlet	468.57 lb/hr	445.69	514.76	476.34	#6*#8/100
10. Baghouse outlet particulate	0.64 lb/hr	1.37	9.34	3.78	From Table 3-13b
11. Comb. carbon in BH outlet emis.	0.01 percent	0.09	0.10		From Table 5-50
12. Ash in BH outlet emissions	99.99 percent	99.91	99.90		100-#11
13. Ash in BH outlet emissions	0.64 lb/hr	1.37	9.33	3.78	#10*#12/100
14. Baghouse catch	491.03 lb/hr	457.15	513.84	487.34	#6-#10
15. Comb. carbon in baghouse catch	10.62 percent	7.36	6.31		From Table 5-51
16. Ash in baghouse catch	89.38 percent	92.64	93.69		100-#15
17. Ash in baghouse catch	438.88 lb/hr	423.51	481.42	447.94	#14*#16/100
18. Total ash out	439.53 lb/hr	424.88	490.75		#13+ #17
19. Ash in - Ash out	29.04 lb/hr	20.81	24.01	24.62	#9-#18
20. Ash out/ash in	0.94	0.95	0.95	0.95	#18/#9
SCR Reactor					
21. Baghouse outlet particulate	0.64 lb/hr	1.37	9.34		#10
22. Comb. carbon in BH outlet emis.	0.01 percent	0.09	0.10		From Table 5-50
23. Ash in BH outlet emissions	99.99 percent	99.91	99.90		100-#22
24. Ash in BH outlet emissions	0.64 lb/hr	1.37	9.33	3.78	#21*#23/100
25. SCR outlet particulate	77.15 lb/hr	55.77	82.09	71.67	From Table 3-13b
26. Comb. carbon in SCR outlet	0.06 percent	0.00	0.07		From Table 5-50
27. Ash in SCR outlet emissions	99.94 percent	100.00	99.93		100-#26
28. Ash in SCR outlet emissions	77.10 lb/hr	55.77	82.03	71.63	#25*#27/100
29. Ash in - Ash out	-76.46 lb/hr	-54.40	-72.70	-67.85	#24-#28
30. Ash out/ash in	119.86	40.72	8.79	56.45	#28/#24

TABLE 3-15. (Continued)

TABLE 3-16. ASH MATERIAL BALANCE RESULTS (percent)^(a)

	7/19/93	7/22/93	7/24/93	Average
Baghouse	93.8	95.3	95.3	94.8

(a) Output as compared to input.

TABLE 3-17. SULFUR MATERIAL BALANCE CALCULATIONS

Sulfur Mass Balance

Test Date	M-1 7/19/93	M-2 7/22/93	M-3 7/24/93	Average	Comments
Flue gas loadings					
SNOx Inlet (Location 18)					
1. Gas flow rate, dry	Ncm/min	1767.00	1748.00		From Table 3-13b
2. Sulfur loading	ug/Ncm	18853.14	24061.21		From Table 5-19
3a. Sulfur emissions	g/hr	2306.06	2523.54		#1*#2*60/1000000
3b. Sulfur emissions	lb/hr	5.08	5.56		#3a/453.6
4. SO2 in flue gas	ppm	2086.00	2061.00		From Table 2-5
5. SO2 in flue gas	Ncm/min	3.76	3.42		#1*#4
6. SO2 in flue gas	lb/hr	1421.96	1294.79		#5*35.3*60*.08062*64.06/28.9
7a. Sulfur in SO2 in flue gas	lb/hr	711.64	648.00		#6*32.06/64.06
7b. Sulfur in SO2 in flue gas	g/hr	322801.46	293933.69		#7a*453.6
8a. Total sulfur in flue gas	lb/hr	716.73	652.41		#3b+#7a
8b. Total sulfur in flue gas	g/hr	325107.52	295932.50		#3a+#7b
SNOx Outlet (Location 21)					
9. Gas flow rate, dry	Ncm/min	2098.65	2142.00		From Table 3-13b
10. Sulfur loading	ug/Ncm	17250.13	15004.85		From Table 5-20
11a. Sulfur emissions	g/hr	2172.12	1928.42		#9*#10*60/1000000
11b. Sulfur emissions	lb/hr	4.79	4.25		#11a/453.6
12. SO2 in flue gas	ppm	83.00	67.00		From Table 2-5
13. SO2 in flue gas	Ncm/min	0.17	0.14		#9*#12
14. SO2 in flue gas	lb/hr	65.93	54.32		#13*35.3*60*.08062*64.06/28.9
15a. Sulfur in SO2 in flue gas	lb/hr	33.00	27.18		#14*32.06/64.06
15b. Sulfur in SO2 in flue gas	g/hr	14966.69	12331.09		#15a*453.6
16a. Total sulfur in flue gas	lb/hr	37.78	31.44		#11b+#15a
16b. Total sulfur in flue gas	g/hr	17138.81	14259.51		#11a+#15b
Sulfur mass balances					
Total SNOx System					
17. Sulfur in BH inlet gases	lb/hr	716.73	652.41		#8a
18. Baghouse catch	lb/hr	491.03	457.15		From Table 3-15
19. Sulfur in baghouse catch	ug/g	10679.99	10646.62		From Table 5-25
20. Sulfur in baghouse catch	lb/hr	5.24	4.87		#18*#19/1000000
21. SO2 reactor waste	lb/hr	0.00	0.00		Assumed

TABLE 3 -- 17. (Continued)

22.	Sulfur in SO ₂ reactor waste	ug/g	0.00	0.00	0.00	No data
23.	Sulfur in SO ₂ reactor waste	lb/hr	0.00	0.00	0.00	#21*#22/1000000
24.	Acid drain	lb/hr	2209.70	2021.40	2117.58	From SNOx system analysis
25.	Sulfur in acid	ug/g	307300.00	307300.00	307300.00	From Table 5--26
26.	Sulfur in acid	lb/hr	679.04	621.18	650.73	#24*#25/1000000
27.	Sulfur in SO ₂ tower outlet gases	lb/hr	37.78	31.44	41.43	#16a
28.	Sulfur out	lb/hr	722.07	657.48	698.62	#20+ #23+ #26+ #27
29.	Sulfur in -- sulfur out	lb/hr	-5.34	-5.07	-10.64	#17 - #28
30.	Sulfur out/sulfur in		1.01	1.01	1.02	#28/#17
<hr/>						
Sulfur Emission Factors						
Firing Rate						
31.	Equivalent firing rate	lb/hr	25827.80	26433.43	26803.34	From Table 3--13b
32.	Coal heating value	Btu/lb	12249.00	12249.00	12249.00	From Table 5--52
33a.	Firing rate	10 ⁶ Btu/hr	316.36	323.78	328.31	#31*#32/1000000
33b.	Firing rate	MJ/hr	333764.84	341591.15	346371.33	#33a*1055
Boiler emissions						
34a.	Sulfur emissions	g/hr	325107.52	295932.50	312070.75	#8b
34b.	Sulfur emissions	lb/hr	716.73	652.41	687.99	#8a
35a.	Sulfur emissions factor	ug/MJ	974061.62	866335.40	900971.64	#34a*1000000/#33b
35b.	Sulfur emissions factor	lb/10 ⁶ Btu	2265509.27	2014955.58	2095513.84	#34b*1000000/#33a
SNOx emissions						
36a.	Sulfur emissions	g/hr	14966.69	12331.09	14544.86	#16b
36b.	Sulfur emissions	lb/hr	37.78	31.44	41.43	#16a
37a.	Sulfur emissions factor	ug/MJ	44842.02	36098.98	41992.11	#36a*1000000/#33b
37b.	Sulfur emissions factor	lb/10 ⁶ Btu	119431.67	97090.67	126177.27	#36b*1000000/#33a
Removal Efficiencies						
38.	Total SNOx system	percent	94.73	95.18	93.98	(#35b--#37b)*100/#35b
					94.63	

TABLE 3-18. SULFUR MATERIAL BALANCE RESULTS (percent)

	7/19/93	7/22/93	7/24/93	Average
SNOX System	100.7	100.8	101.6	101.3

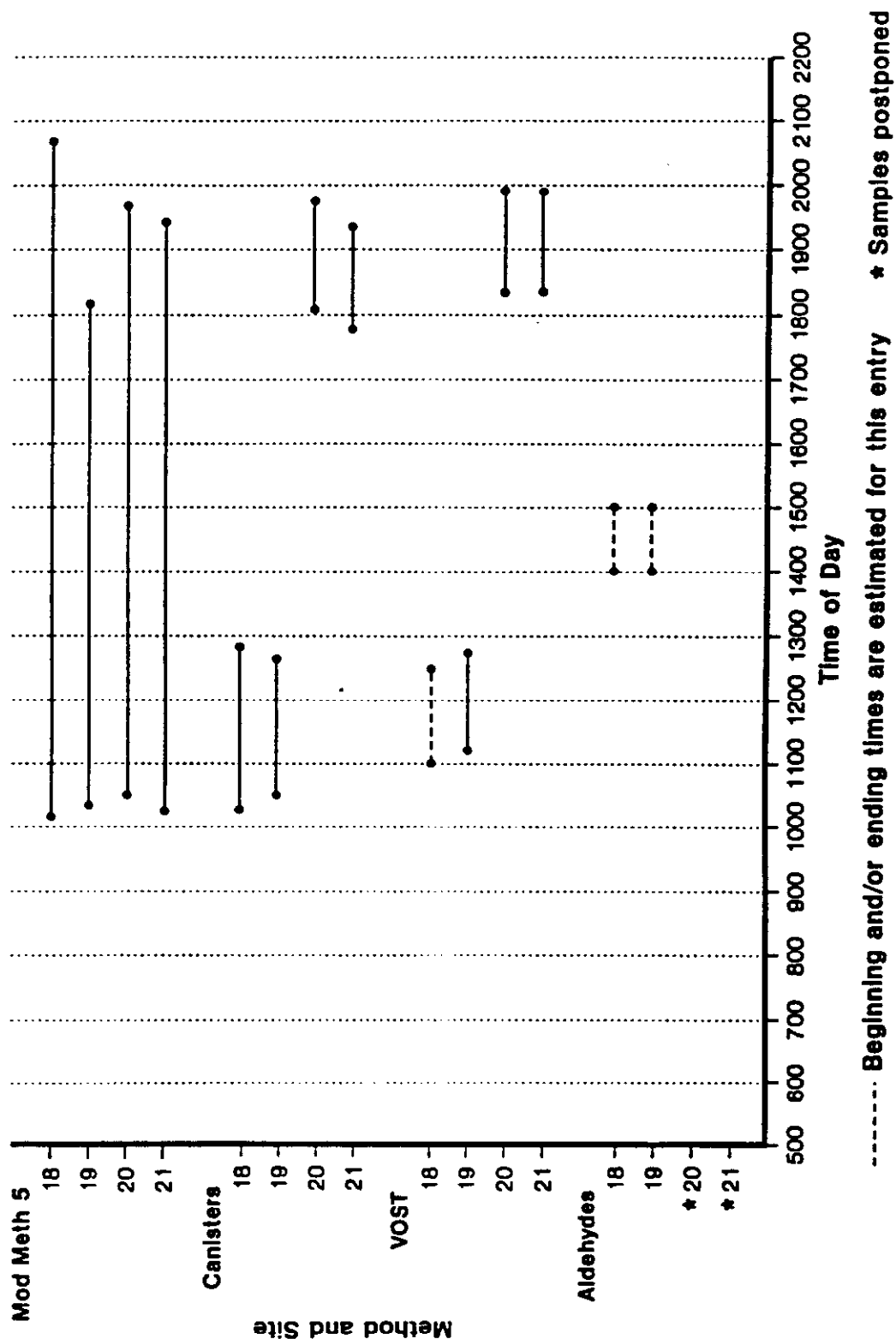


Figure 3-1a. Flue gas sampling schedule at Niles-SNOX, July 18, 1993

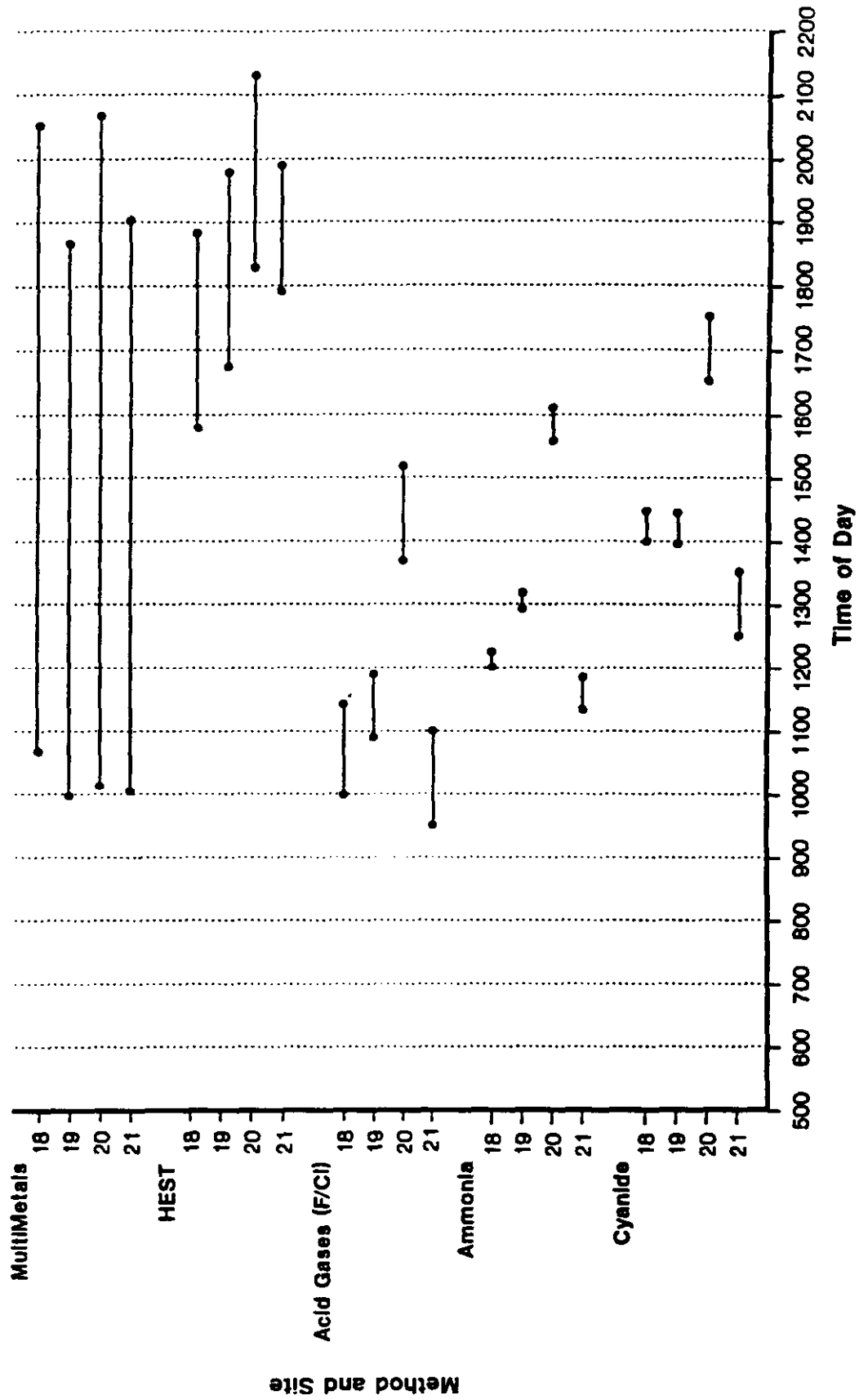


Figure 3-1b. Flue gas sampling schedule at Niles-SNOX, July 19, 1993

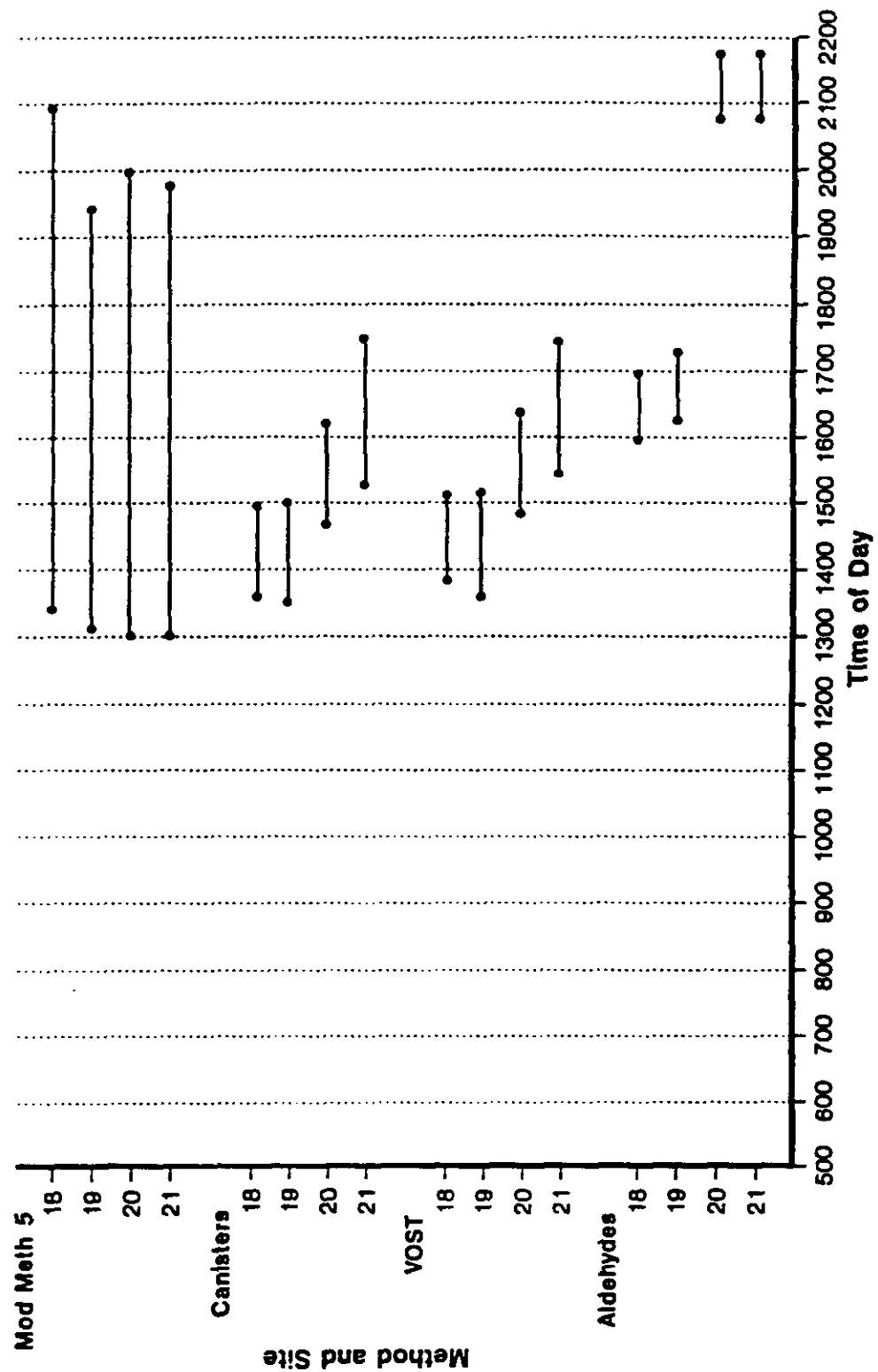


Figure 3-1c. Flue gas sampling schedule at Niles-SNOX, July 21, 1993

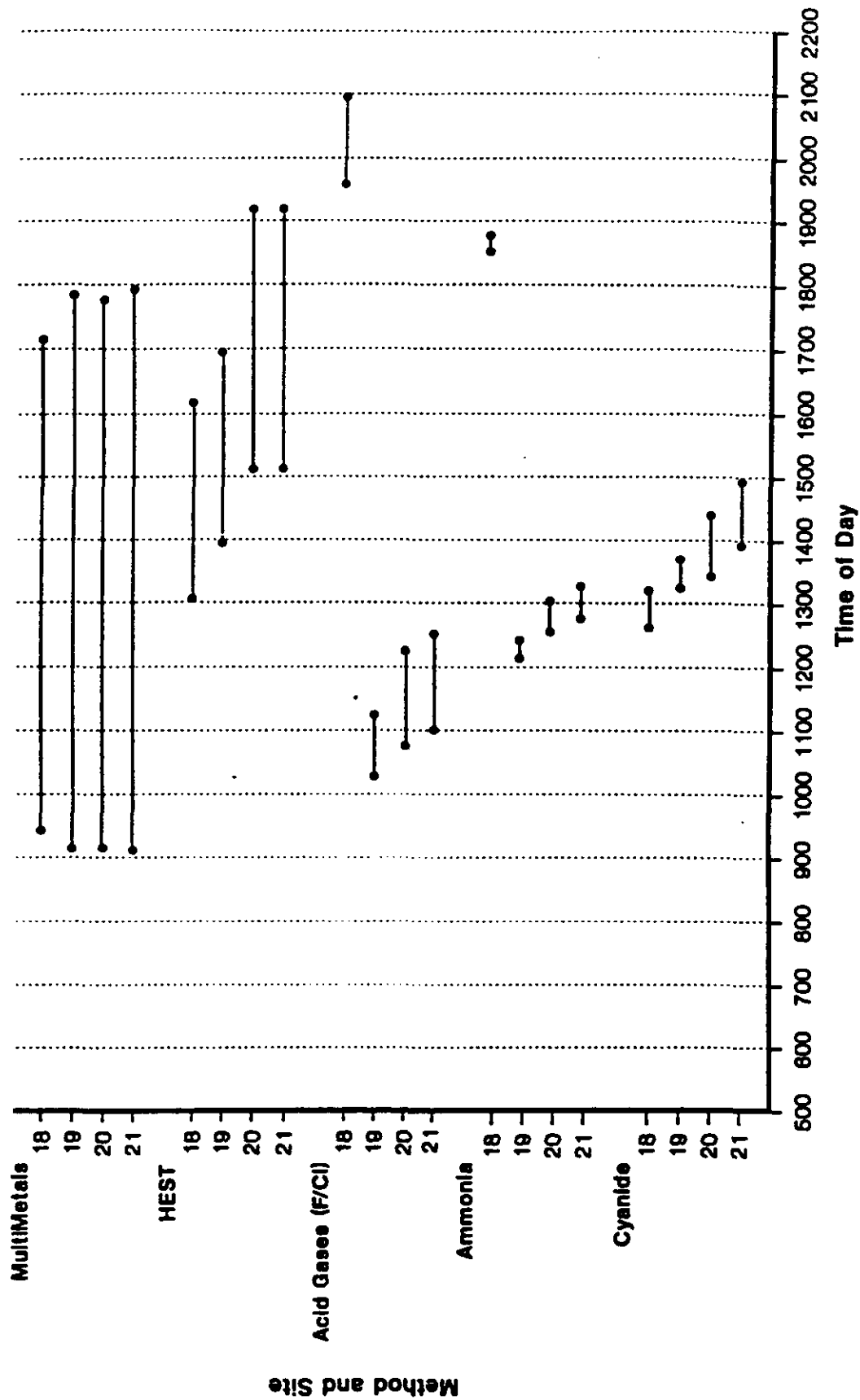


Figure 3-1d. Flue gas sampling schedule at Niles-SNOX, July 22, 1993

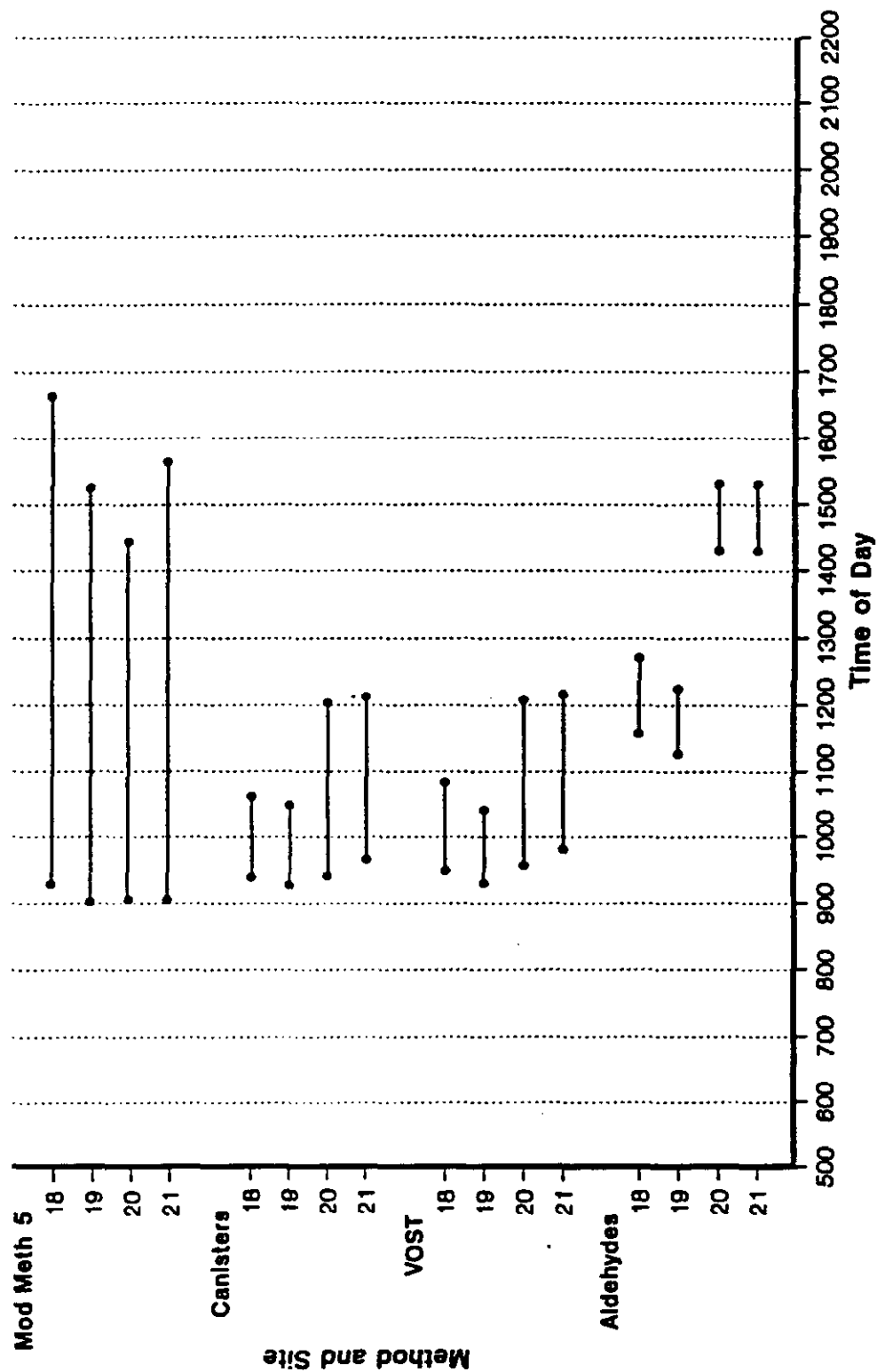


Figure 3-1e. Flue gas sampling schedule at Niles-SNOX, July 23, 1993

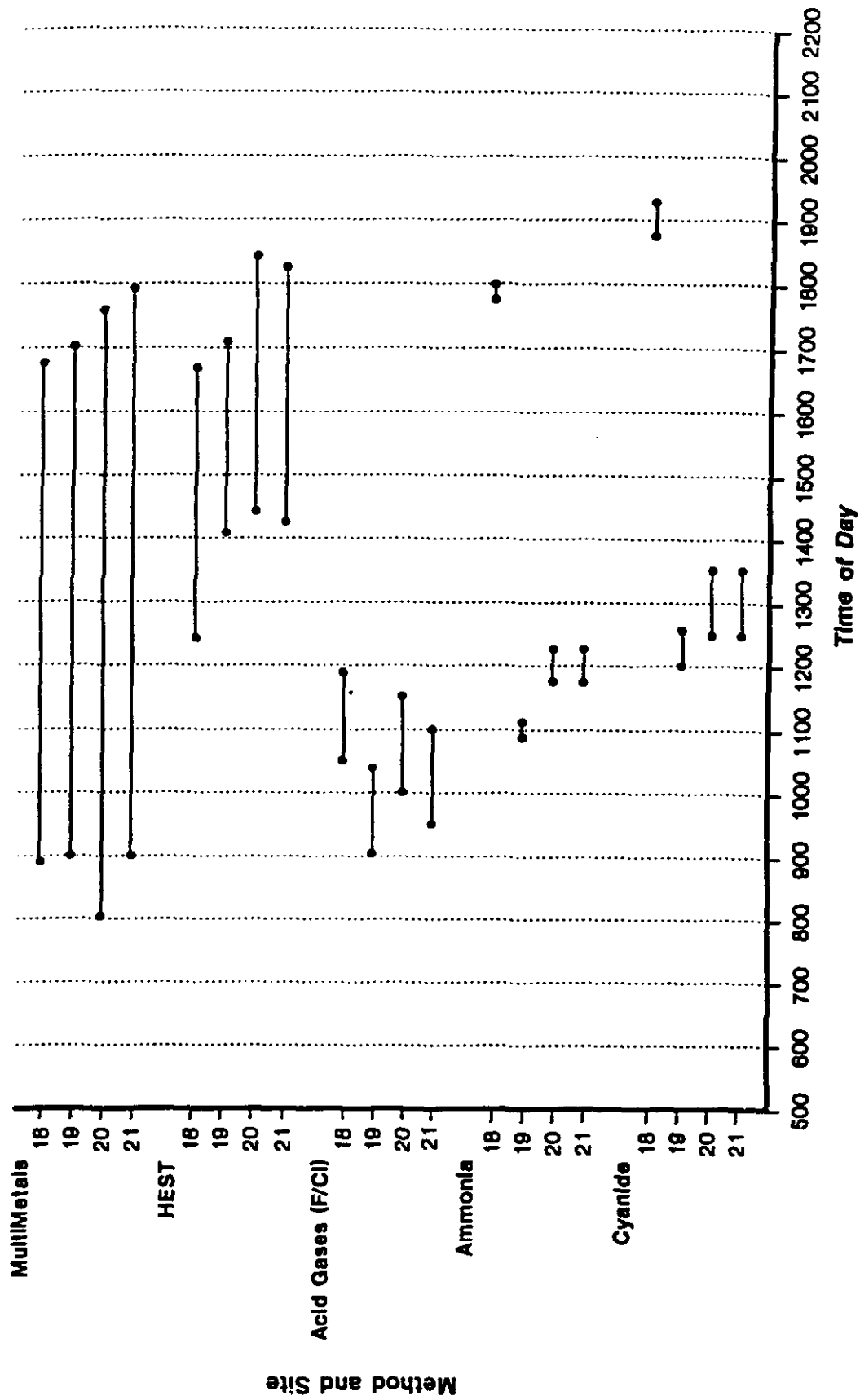


Figure 3-1f. Flue gas sampling schedule at Niles-SNOX, July 24, 1993

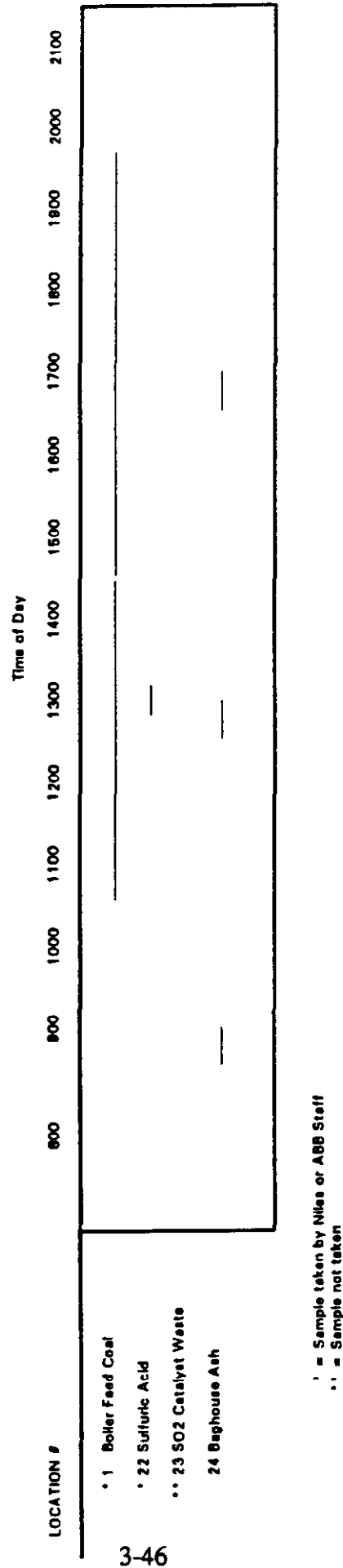


Figure 3-2a. Solid and liquid sample collection schedule, Niles-SNOX, July 18, 1993

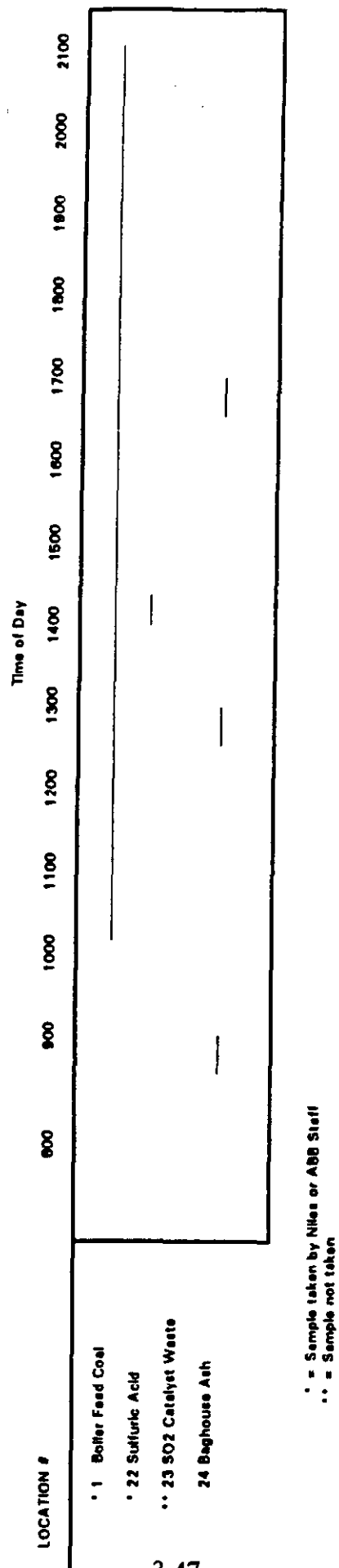


Figure 3-2b. Solid and liquid sample collection schedule, Niles-SNOX, July 19, 1993

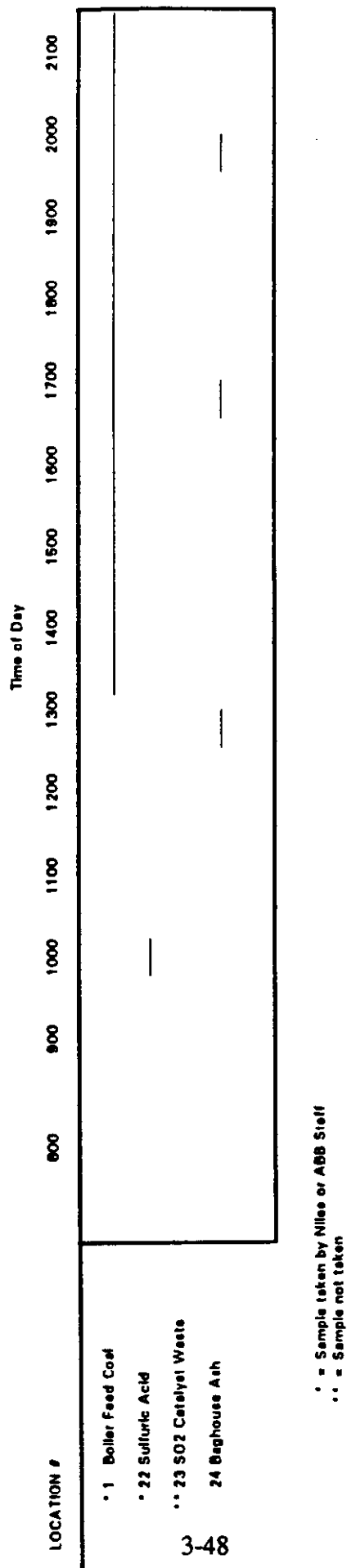


Figure 3-2c. Solid and liquid sample collection schedule, Niles-SNOX, July 21, 1993

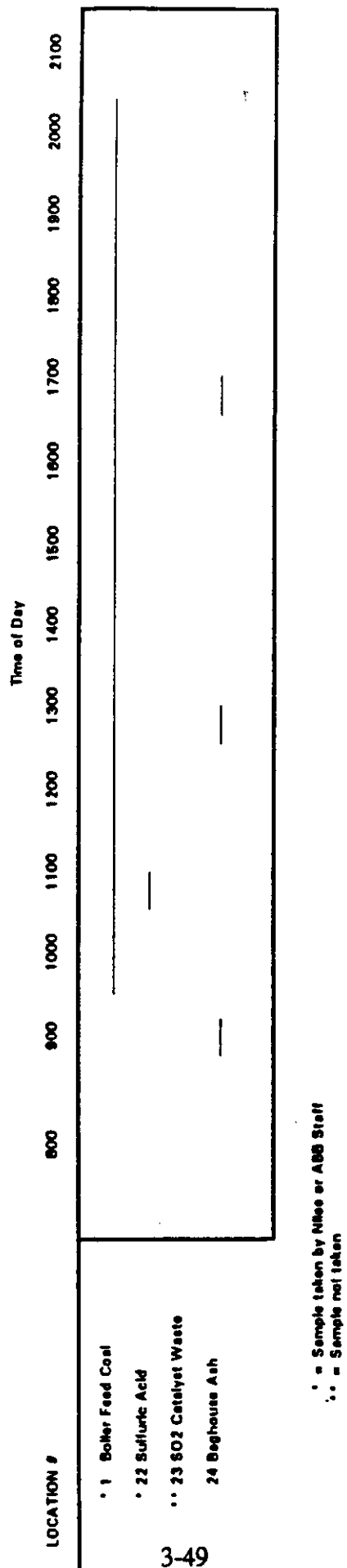


Figure 3-2d. Solid and liquid sample collection schedule, Niles-SNOX, July 22, 1993

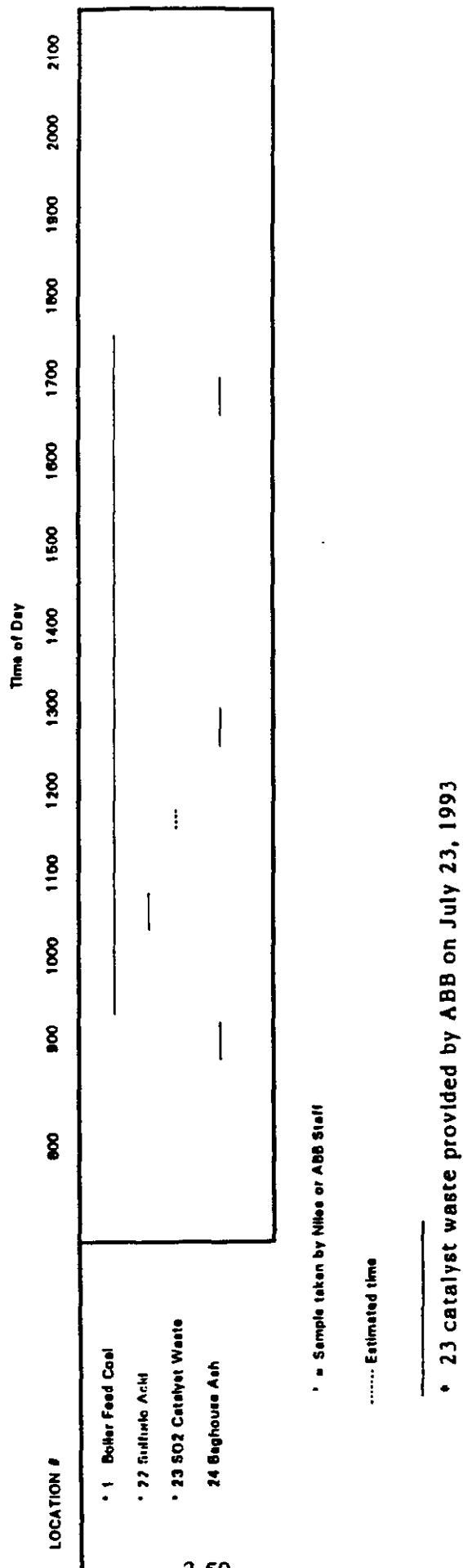


Figure 3-2e. Solid and liquid sample collection schedule, Niles-SNOX, July 23, 1993

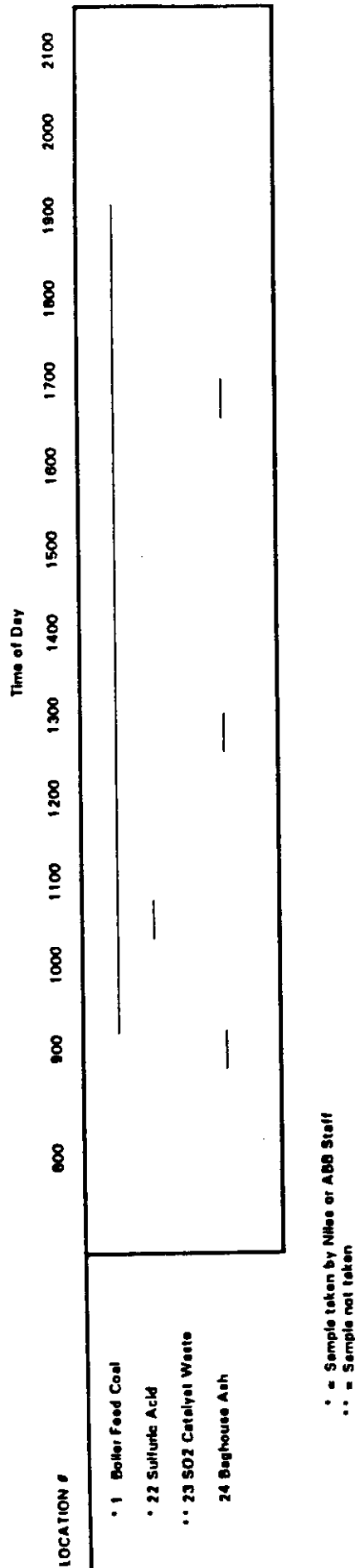


Figure 3-2f. Solid and liquid sample collection schedule, Niles-SNOX, July 24, 1993

4.0 SAMPLE ANALYSIS

4.1 Analytical Methods

A summary of the sample preparation procedures and analytical techniques used to analyze the gas, solid, and liquid samples collected on this project are listed in Table 4-1 along with the identity of the laboratory conducting the analyses. Specific details of the analytical procedures are provided in the **Analytical Plan** prepared for this project.* Any deviations from the analytical procedures cited in the Analytical Plan are described in Appendix F, and QA/QC data associated with the analyses are summarized in Appendix E. Requirements for the preservation and storage of samples after collection are detailed in Table C-2, Appendix C.

*Niles-SNOX Analytical Plan, DOE Contract DE-AC22-93PC93251, July 16, 1993.

TABLE 4-1. LABORATORY ANALYTICAL PROCEDURES

Sample Matrix	Analyte Class	Sample Preparation Procedure	Analytical Technique	Analytical Laboratory
Gas ^(a) (includes particulate in gas stream)	Elements			
	Ba, Be, Cr, Co, Mn, Ni, Vi, B, Mo, Cu, Al, Si, Ti, K, Na	Acid digestion ^(d)	ICP-AES	CTE
	As, Sb, Se, Pb, Cd	Acid digestion ^(d)	GF-AAS	CTE
	Hg	Acid/KMnO ₄ digestion ^(d)	CV-AAS	Battelle ^(b)
	Ammonia/Cyanide	None	ISE	Battelle
	Anions	CO ₃ ⁼ /HCO ₃ ⁻ Extraction ^(e)	IC	Battelle
	VOC ^(a)	None	GC/MS	Chester
	PAH/SVOC	Solvent Extraction	GC/MS	Battelle
	Aldehydes	None	HPLC/UV	Battelle
	Radionuclides	-	Gamma radiation	IT
Solid	Ultimate/Proximate and Related Analyses	-	ASTM	CTE
	Elements			
	Ba, Be, Cr, Co, Mn, Ni, Vi, B, Mo, Cu, Al, Si, Ti, K, Na	Acid digestion	ICP-AES	CTE ^(c)
	As, Sb, Se, Pb, Cd	Acid digestion	GF-AAS	CTE ^(c)
	Hg	Acid/KMnO ₄ digestion	CV-AAS	CTE ^(c)
	Anions	CO ₃ ⁼ /HCO ₃ ⁻ extraction	IC	Battelle
	PAH/SVOC	Solvent extraction	GC/MS	Battelle
	Radionuclides	-	Gamma radiation	IT
	Ultimate/Proximate and Related Analyses	-	ASTM	CTE

TABLE 4-1. (Continued)

Sample Matrix	Analyte Class	Sample Preparation Technique	Analytical Technique	Analytical Laboratory
Liquid	Elements			
	Ba, Be, Cr, Co, Mn, Ni, Vi, B, Mo, Cu, Al, Si, Ti, K, Na	Acid digestion	ICP-AES	CTE
	As, Sb, Se, Pb, Cd	Acid digestion	GF-AAS	CTE
	Hg	KMnO ₄ digestion	CV-AAS	CTE
	Ammonia/Cyanide	None	ISE	Battelle
	Anions	None	IC	Battelle
	VOC	Helium purge	GC/MS	Zande
	PAH/SVOC	Solvent extraction	GC/MS	Battelle
	Aldehydes	DNPH derivatization	HPLC/UV	Battelle

VOC = Volatile organic compounds.

PAH/SVOC = Polynuclear aromatic hydrocarbons and other semivolatile organic compounds.

ICP-AES = Inductively coupled plasma atomic emission spectrometry.

GF-AAS = Graphitic furnace atomic absorption spectrometry.

CV-AAS = Cold vapor atomic absorption spectrometry.

ISE = Ion selective electrode.

IC = Ion chromatography.

GC/MS = Gas chromatography/mass spectrometry.

HPLC/UV = High performance liquid chromatography/ultraviolet detection.

ASTM = ASTM-specified techniques.

CTE = Commercial Testing and Engineering Laboratory.

IT = International Technology, Inc.

(a) Does not include HEST samples and VOC-canister samples for which procedures and results are presented in Section 7.

(b) Filters were analyzed for Hg by CTE.

(c) Coal samples were also analyzed by Proton Induced X-Ray Emission techniques for quality control comparison purposes.

(d) As specified in Method 29.

(e) For anions in gas samples, impinger solutions were analyzed directly without preparation; particulate filters were extracted with carbonate/bicarbonate (CO₃²⁻/HCO₃⁻) eluent; and the extracted solution was analyzed.

5.0 ANALYTICAL RESULTS

Analytical results are presented in Section 5. Analytical data were reduced according to specifications established by DOE. These specifications are reproduced exactly below (with Battelle interpretation in italics):

"TREATMENT OF NON-DETECTS, VALUES OUTSIDE OF THE CALIBRATION RANGE AND BLANKS

Treatment of non-detects (analytical results for which the concentration of the species of interest is below the detection limit of the method) and blank values is of critical importance in this program because detection levels and blank concentrations are often on the same order of magnitude as sample values. When the results are then used for risk assessments or policy decisions, treatment of the data becomes important. This discussion describes how blank and non-detect values are to be treated in presenting/developing reported results.

Non-Detects

The discussion presented below explains how averages, sums, and reported emission values are to be calculated for all species given various combinations of detected and non-detected values.

All values detected. The arithmetic average or sum is taken, as appropriate. No special techniques required.

All values below the detection limit. For individual test runs or species, the data are to be reported as "ND < (detection limit)." For cases where all three runs (*or multiple species*) are below the detection limit, the average is reported as non-detected less than the average detection limit of the three runs (*species*).

Some values are detected and some are non-detects. As an approximation, half of the detection limit for nondetect values and the actual value for detects will be used to determine reported values. As an example of averaging, an average for three test runs with results of 10, 8, and ND < 6 would be 7. As an example for summing (such as for mercury fractions), individual species values of 50, ND < 1 and ND < 2 would be summed to provide a value of 50 + .5 + 1 or 51.5. In reporting these types of sums or averages no "<" sign is used. The only exception to this rule occurs when the average (*or sum*) is less than the highest detection limit of the non-detected values. In this case, the averages or sums is reported as "ND < (the highest detection limit)." For example, 5, ND < 4 and ND < 3 would be reported as "ND < 4."

This approach is also used to obtain test train totals which required analyses of separate fractions for each individual run. Specifically, the volatile, metals, and anion test train totals for each run are obtained by addition of test train fractions which were analyzed separately.

Fractions from the volatile test train included separate analyses of the tenax and tenax/charcoal tubes for each sample period. Separate

analyses were conducted on the filterable and gaseous test train components for both the metals and anion test trains.

Detection limit ratio. These methods of treating the data may result in some loss of information in going from raw data to final values. Specifically, what is often lost is the amount of a final emission value that is attributable to detection limits and the amount that is attributable to measured values. In order to quantify and present this information, all results in this report are presented along with the "Detection Limit Component Ratio," (*DL Ratio*) which is calculated as the ratio of the contribution of detection limit values to a final emission result.

For example, a set of three values of 16, ND < 6, and ND < 5 should be reported as 7, with a detection limit ratio of 26% $((3+2.5)/(16+3+2.5))$, while a set of values of 12, ND < 6, and 9 should be reported as 8, with a detection limit ratio of 13%. The different ratios provide insight as to the extent something is "really there," and hopefully can help provide better information to those making decisions on risk and policy issues.

Values Outside the Calibration Range

It is possible that the reported lab data will be outside the calibration range of the instrument. Data reported below the lower detection will be flagged with a qualifier (e.g., "J"). Data with the "J" flag will have been tentatively identified and tentatively quantified. Data reported above the upper detection limit will be flagged with a qualifier (e.g., "E"). Data with the "E" flag will have been positively identified and tentatively quantified. Data with both qualifiers will be estimates. Consider J and E values to be quantitatively representative when calculating averages. Neither flag should cause a value to be weighted more or less important. The J and E data qualifiers should appear in the respective laboratory analytical report. The data qualifiers need not appear on the calculated data summaries.

Blank Values

The level and treatment of blank values is important in interpreting data, since in some cases species are detected but not at levels significantly higher than blanks. In these cases measured values may not represent emissions, but rather just limitations of the method. However, most of the test methods used in this program either do not allow subtraction of blanks or are silent on how to treat blank values.

When a method does not specify how the sample will be blank corrected, the appropriate blank train values should be subtracted. Laboratory and site/reagent blanks will be analyzed and the results evaluated for identification of contamination. If a sample compound is blank corrected the data will be flagged by a "B". If the value is blank corrected below the detection limit it should be reported as "ND < (detection limit) BC." A "C" flag indicates that the blank value was greater than the sampled value. In no case should the blank corrected values be reported below the method detection limit."

Gas samples and train blanks were corrected for field reagent blanks, where available. After field reagent blank corrections, samples were corrected for train blanks. These blank corrections are designated in footnotes to the Section 5 tables rather than flagged with a "B" as indicated in the above DOE specifications. Any additional flags used to qualify the

analytical data are included as appropriate in the Section 5 tables with defining footnotes in each table where used.

Averages were calculated for the three samples collected at a single location on each of the three sampling days (i.e., inorganic or organic). Specifications provided by DOE, as reproduced above, were used to calculate averages. A standard deviation (SD) was calculated for the three sampling days using a sample population (i.e., using N-1 in the denominator). It must be noted that results from the three individual measurements shown in Section 5 tables were used to conduct three separate calculations of mass balances, removal efficiencies, and power plant emissions, in Section 6. The average result of those three separate calculations was then calculated. The average concentrations shown in Section 5 were not used in such calculations.

It should be noted that values for the DL Ratio were calculated and are shown in subsequent tables only when a detected value is shown for the average, not when the average is shown as a non-detected value. In other words, an average value which is itself labelled as a non-detect (i.e., ND <), whether based entirely or partially on individual non-detected values, is not shown with an associated DL Ratio value. This approach eliminates unnecessary repetition of high DL Ratio values for results which are already indicated as non-detected values.

In parts of Section 5 blank values for analytes in flue gas are shown, in units of (e.g.) $\mu\text{g}/\text{Nm}^3$. The blank results shown were calculated from blank samples using a representative or average sampled flue gas volume; as such they are for illustration only. Blank subtraction from actual samples was always done by subtracting the mass of analyte in the blank, then dividing by the sampled flue gas volume appropriate for each sample.

Results are reported at standard conditions of 0°C and 760 mm Hg and dry conditions.

5.1 Elements

5.1.1 Gas Samples

Tables 5-1 through 5-9 show the concentrations of elements measured in flue gas samples for the SNOX process. Data are presented for elements in particulate matter ($\mu\text{g/g}$) and for total element concentration (vapor plus particle phase) in $\mu\text{g/Nm}^3$, where Nm^3 denotes normal cubic meters. Blank sample results are included in Table 5-9.

Vapor/particle distributions of elements are discussed as a Special Topic in Section 7.1.1.

Some filter blanks showed high levels of aluminum, potassium and sodium. This result is not unexpected as high blank values in filters have been documented.**

Consequently there is concern that some filters used to collect samples may also have had high levels of these elements in the filters themselves. For this reason, a notation has been made to Tables 5-1 through 5-8. This issue is discussed in Appendix F.

Boron was not determined in the gas samples because it was required to be used to form a complex with excess hydrofluoric acid after microwave digestion of the samples. Hydrofluoric acid, although specified for use in EPA Method 29, can react with glassware or with the glass mixing chamber of the ICP analyzer. Therefore the excess hydrofluoric acid was effectively removed from the system by forming a complex with boric acid. Addition of boric acid negated the analysis of boron.

Silicon was not determined in sample fractions collected by the two cyclones and by the filter. The commercial laboratory that conducted the analyses did not report data for silicon because the excess hydrofluoric acid used in sample preparation can interfere with results for silicon (see Appendix F). The silicon data reported for the flue gas samples are results for the front half rinse of the sampling trains (i.e., sampling probe, flexible line, front half filter housing) and back half of the sampling trains (i.e., back half of the filter housing, empty impinger and $\text{HNO}_3/\text{H}_2\text{O}_2$ impingers). Therefore these data do not represent all silicon in the collected particulate matter. An estimate of the presence of silicon in the

**Berg, Torunn; Royset, Oddvar; and Eiliv Steinnes. "Blank Values of Trace Elements in Aerosol Filters Determined by ICP-MS", Atmospheric Environment, Vol. 27A, No. 15, pp 2435-2439, 1993.

sample is better obtained by multiplying the ratio of silicon/aluminum in the coal (1.8, see Table 5-10) or baghouse ash (1.7, see Table 5-12) by the reported aluminum concentration in each sample. Because of this bias and the scatter in the results for silicon, an emission factor for silicon was not calculated in Section 6.

Mercury, as expected, as found to be present predominantly in the vapor phase. The tables containing mercury concentrations in $\mu\text{g/g}$ (Tables 5-1, 5-3, 5-5, and 5-7) show mercury concentrations at the baghouse inlet, baghouse outlet, and SCR reactor outlet (Locations 18, 19, and 20) generally less than one $\mu\text{g/g}$. Two exceptions are shown: baghouse outlet on July 19 (19.4 $\mu\text{g/g}$) and SCR reactor outlet on July 19 (5.23 $\mu\text{g/g}$). Turning first to the baghouse outlet, in this sample all mercury (above train blanks) that was found in the front half of the sampling train (i.e., particulate phase) was found in the acetone rinse. The weight of the residue in the acetone rinse for this sample was only 0.018 g yielding the value of 19.4 $\mu\text{g/g}$. The samples on July 22 and July 24 also had mercury detected in the acetone rinse, but subtraction of the blank forced these values to zero. Hence results are reported in Table 5-3 as less than the detection limit. The value shown for July 19 is considered by Battelle to be an "outlier", and it is not used in calculating mass balances or removal efficiencies. Likewise the value of 5.23 $\mu\text{g/g}$ for mercury at Location 20 is also considered an outlier.

Comments pertinent to specific sampling locations are provided below.

5.1.1.1 Location 18 - Baghouse Inlet. To evaluate the data obtained at this location ahead of control systems for particulate matter, the average concentrations of the elements in Table 5-2 were used to calculate a total average concentration. The data for aluminum, silicon (estimated using the procedure described above), potassium, titanium, and sodium were used to calculate concentrations as the oxides Al_2O_3 , SiO_2 , K_2O , TiO_2 , and Na_2O . The average total concentration was computed to be about 1,050 mg/Nm^3 . When Fe_2O_3 is added into the calculation (scaling to the other oxides from the round robin coal analyses (see Appendix B)) and the three percent carbon is accounted for, the sum of the oxides and carbon is about 1,400 mg/Nm^3 or about 68 percent of the measured particulate matter. This calculation indicates that problems with the major elements may be significant but that they do account for the majority of the measured particle mass loading at Location 18.

5.1.1.2 Location 19 - Baghouse Outlet. The concentrations of particulate matter reported for the three days, from Table 2-2, is 3.0, 6.0, and 40.7 mg/Nm³. The corresponding concentrations of the elements in Table 5-4, with five major elements computed as oxides, are about 4.9, 1.4, and 13.1 mg/Nm³. With the exception of the data for July 19 in which the elemental data sum to more than the measured particulate mass, the comparison is consistent with higher particulate mass on July 24 than either July 19 or July 22.

Referring to Table 5-3, the reported concentration of aluminum in fly ash of 177,000 µg/g is not consistent (too high) with the coal analysis, aluminum content of fly ash at the inlet to the baghouse, or the other two days at this location. Therefore, this value was not used in computing the reported average in this table.

There is significant variation in the reported data for aluminum at this location (relative standard deviation of nearly 100 percent). The aluminum concentration reported for July 24 of 1,550 µg/Nm³ was heavily influenced by the front half rinse. Subtraction of the high train blank for aluminum (6,810 µg/Nm³, see Table 5-9) made the reported aluminum concentration for the front half portion of the sample for July 19 and July 22 go nearly to zero.

The barium concentrations vary from 0.52 to 2.66 µg/Nm³. The bulk of the barium was found in the front half rinse of the sampling train. The values vary significantly for the front half portions of the three samples. The train blank was high relative to the measured values in the samples, and subtraction of one relatively large number from another can increase the variability in reported concentrations.

Reported chromium concentrations vary from 1.14 to 8.61 µg/Nm³. The chromium concentration in the front half rinse was much higher for the sample collected on July 24 than for the other two samples. Nickel is also high for his day. These reported concentrations may be the result of contamination of the sample by stainless steel. Molybdenum, which is present in some stainless steels, is not elevated compared to its reported concentrations on the other two days. The same type of contamination may also be responsible for the reported values for July 22.

The results for sodium show values of 1,030, 131, and 2,270 µg/Nm³. This trend is also seen in reported concentrations for aluminum, barium, and potassium, although the

variation is more pronounced for sodium. Sodium was detected in the front half rinse and back half of the sampling train but not on the filter portion of the samples.

The reported levels of potassium, selenium, silicon, and sodium in Table 5-3 are variable and high. An explanation for the results is not available, and little confidence can be put in these results. Potassium, silicon, and sodium had relatively high train blanks which may have contributed to the variability in reported numbers.

5.1.1.3 Location 20 - SCR Reactor Outlet. The particulate matter concentrations at this location are reported in Table 2-2 as 349, 248, and 360 mg/Nm³ for July 19, 22 and 24, respectively. These data are considered to be artifacts generated by reaction of ammonia with sulfur compounds in the sampling train (see the discussion in Sections 5.2 and 5.3). The summation of elemental concentrations reported as oxides for five elements yielded values of about 23 (without manganese and potassium), 4, and 6 mg/Nm³. This is consistent with the anion and ammonia data which lead to the conclusion that the reported concentrations of particulate matter at this location consist primarily of ammonium sulfates.

The reported data for July 19 are in general much higher than for the other two sampling days. It was on July 19 that severe plugging of the filters occurred, and five filters had to be collected (see Section 3.2.4). Also, problems occurred with the sampling train when the potassium permanganate (KMnO₄) solution was sucked forward into the first set of impingers. The reported data for manganese and potassium are believed to be artifacts resulting from this occurrence. Note that the ratio of reported concentrations of potassium/manganese is 0.85, and the ratio of their atomic weights is 0.71. These ratios are consistent with the hypothesis that the Mn and K arose from the KMnO₄ impinger solution.

5.1.1.4 Location 21 - WSA Condenser Outlet. At Location 21 the average of the reported concentrations of particulate matter in Table 2-2 is 49 mg/Nm³. This is believed to be primarily sulfuric acid mist, not fly ash. The summation of the elemental data in Table 5-8 according to the same procedures as used for the other locations yields a value of about 2 mg/Nm³. The ratio of mass from the oxides to reported particulate mass at this location is much less than at Location 18, for example. This calculation is consistent with the assignment of the majority of the reported mass at Location 21 as other than fly ash.

Note that the reported aluminum concentration for July 22 is less than the detection limit. Aluminum was not reported as detected in the filter sample for this day, although it was detected in the other two filter samples. The reported value is not correct; an explanation for the result was not found.

Barium is reported as $0.609 \mu\text{g}/\text{Nm}^3$ for the sample collected on July 19 but less than the detection limits on the other two days. Barium was detected in the front half rinse of the sampling train for the July 19 sample but not in the other two samples. Subtraction of the relatively high train blank from the sample results led to variability in the reported concentrations.

Chromium and nickel show elevated concentrations for July 22. These elements were in high concentration in the front half rinse. These reported concentrations are ascribed to contamination by stainless steel material. However, molybdenum, which is present in some stainless steels, is only slightly elevated compared to the other two days.

TABLE 5-1. ELEMENTS IN PARTICULATE MATTER FROM BAGHOUSE INLET (LOCATION 18) ($\mu\text{g/g}$)

Analyte	N-18-MUM-719	N-18-MUM-722	N-18-MUM-724	AVERAGE	DL RATIO	SD
Aluminum	55200	89700	79600	74800		17800
Potassium	18300	23600	20500	20800		2660
Silicon	265000	173000	203000	214000		46900
Sodium	1890	2550	2980	2470		549
Titanium	6510	7180	6670	6790		350
Antimony	47.7	40.9	40.2	43		4.2
Arsenic	1750	1410	1300	1490		235
Barium	466	696	680	614		128
Beryllium	37.7	36.4	32.5	36		2.7
Boron	NA	NA	NA	NA		NA
Cadmium	5.00	3.11	1.22	3.1		1.9
Chromium	292	286	253	277		21
Cobalt	88.8	100	91.9	94		6.0
Copper	412	429	367	402		32
Lead	489	369	362	407		71
Manganese	300	275	231	269		35
Mercury	1.03	0.605	0.773	0.80		0.21
Molybdenum	165	113	91	123		38
Nickel	289	319	314	307		16
Selenium	54.1	40.5	38.4	44		8.5
Vanadium	427	437	387	417		26

DL Ratio = Detection limit ratio.

SD = Standard deviation.

NA = Sample not available, sample not analyzed, or data not available.

Silicon value refers to probe rinse only.

Possible contamination of aluminum, potassium, and sodium in filter analysis.

Sample results corrected for train blank.

TABLE 5-2. ELEMENTS IN GAS SAMPLES FROM BAGHOUSE INLET (LOCATION 18) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-18-MUM-719	N-18-MUM-722	N-18-MUM-724	AVERAGE	DL RATIO	SD
Aluminum	123000	181000	180000	161000		33200
Potassium	40400	47600	46700	44900		3920
Silicon	195000	217000	237000	216000		21000
Sodium	4200	5180	6930	5440		1380
Titanium	14500	14500	15100	14700		346
Antimony	107	82.7	91.1	94		12
Arsenic	3960	2870	2980	3270		600
Barium	1040	1400	1540	1330		258
Beryllium	84.4	73.5	73.6	77		6.3
Boron	NA	NA	NA	NA		NA
Cadmium	11.1	6.30	2.79	6.7		4.2
Chromium	656	580	572	602		46
Cobalt	198	202	208	203		4.8
Copper	927	866	831	875		49
Lead	1100	744	818	888		188
Manganese	668	562	524	584		75
Mercury	34.7	26.6	21.7	28		6.6
Molybdenum	367	229	207	268		87
Nickel	653	644	711	669		36
Selenium	121	90.8	101	104		16
Vanadium	954	882	875	904		44

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

Samples corrected for train blank.

Silicon not determined in cyclones and filter.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

TABLE 5-3. ELEMENTS IN PARTICULATE MATTER FROM BAGHOUSE OUTLET (LOCATION 19) ($\mu\text{g/g}$)

Analyte	N-19-MUM-719		N-19-MUM-722		N-19-MUM-724		AVERAGE	DL RATIO	SD
Aluminum	177000	#	31300		38200		34800		NC
Potassium	88800	#	15700		24100		19900		NC
Silicon*	2610		287000		72700		NC		NC
Sodium*	172000		18300		55500		NC		NC
Titanium	1190		444		160		598		532
Antimony	ND <	171	ND <	91.1	ND <	14.4	ND <	92	79
Arsenic		5810		1960		223		2660	2860
Barium		425		83.0		65.1		191	203
Beryllium	ND <	38.2		16.3	ND <	2.59	ND <	38	10
Boron		NA		NA		NA		NA	NA
Cadmium	ND <	38.2	ND <	16.3	ND <	2.59	ND <	19	18
Chromium		182		244		199		208	32
Cobalt	ND <	76.5	ND <	32.5		11.2	ND <	76	14
Copper		38.2		16.3		2.59		19	18
Lead		318	ND <	81.3	ND <	12.8		122	13 % 171
Manganese		182		76.5		96.5		118	56
Mercury		19.4 #	ND <	2.91	ND <	0.471	ND <	1.7	NC
Molybdenum		685		367		56.3		369	314
Nickel	ND <	76.5		71.6		333		148	9 % 161
Selenium*		23100		14900		1690		NC	NC
Vanadium	ND <	18.3		8.03	ND <	1.05	ND <	18	4.7

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

NC = Not calculated.

Silicon value refers to probe rinse only.

Possible contamination of aluminum, potassium, and sodium in filter analysis.

Sample results corrected for train blank.

= Outlier value, not used in calculations.

*Data are highly variable and not consistent with coal, baghouse inlet and baghouse ash results.

TABLE 5-4. ELEMENTS IN GAS SAMPLES FROM BAGHOUSE OUTLET (LOCATION 19) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-19-MUM-719		N-19-MUM-722		N-19-MUM-724		AVERAGE	DL RATIO	SD
Aluminum	522		190		1550		754		709
Potassium	262		95.9		979		446		470
Silicon	3150		3210		3700		3350		302
Sodium	1030		131 #		2270		1650		NC
Titanium	5.67		2.96		6.50		5.0		1.8
Antimony	ND <	0.45	ND <	0.49	ND <	0.51	ND <	0.48	0.03
Arsenic		17.6		12.1		9.23		13	4.3
Barium		1.77		0.52		2.66		1.7	1.07
Beryllium	ND <	0.089		0.143	ND <	0.085	ND <	0.08	0.06
Boron		NA		NA		NA		NA	NA
Cadmium	ND <	0.089	ND <	0.081	ND <	0.085	ND <	0.09	0.0
Chromium		1.14		2.19		8.61 #		1.7	NC
Cobalt	ND <	0.179	ND <	0.161		0.500 #	ND <	0.17	NC
Copper		1.49		1.88		1.57		1.6	0.20
Lead		1.11	ND <	0.448	ND <	0.468		0.52	29% 0.51
Manganese		1.74		2.42		5.01		3.1	1.7
Mercury		28.4		25.9		29.6		28	1.9
Molybdenum		2.23		2.45		2.51		2.4	0.15
Nickel	ND <	0.179		0.524		13.5 #		0.31	NC
Selenium		81.8		97.7		74.2		85	12
Vanadium	ND <	0.050		0.071	ND <	0.044	ND <	0.04	0.03

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

NC = Not calculated.

= Outlier value, not used in calculations (chromium, cobalt, and nickel values are believed to result from contamination by stainless steel).

Samples corrected for N-21-MUM-718 train blank.

Silicon not determined in cyclones and filter.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

TABLE 5-5. ELEMENTS IN PARTICULATE MATTER FROM SCR REACTOR OUTLET (LOCATION 20) (µg/g)

Analyte	N-20-MUM-719		N-20-MUM-722		N-20-MUM-724		AVERAGE		DL RATIO	SD
Aluminum	9350		2330		2010		4560			4150
Potassium	6210 #		1310		717		1010			NC
Silicon	26500		62800		ND <	264 #	44700			NC
Sodium	13700		4570		2930		7070			5800
Titanium	56.7		21.7		20.6		33			21
Antimony	ND <	3.06	ND <	2.35	ND <	1.75	ND <	2.4		0.65
Arsenic		13.3		9.10	ND <	1.75		7.7	4%	6.3
Barium		29.7		7.77		0.875		13		15
Beryllium	ND <	0.716	ND <	0.928	ND <	0.843	ND <	0.83		0.11
Boron		NA		NA		NA		NA		NA
Cadmium		3.62	ND <	0.928	ND <	0.843		1.5	20%	1.8
Chromium		148		22.3		18.0		63		74
Cobalt		2.66	ND <	1.86	ND <	1.69	ND <	1.9		1.0
Copper		155		60.6		30.0		82		65
Lead		18.7	ND <	2.35	ND <	1.75		6.9	10%	10
Manganese		47.9 #		10.7		6.97		8.8		NC
Mercury		5.23 #	ND <	0.456		0.179	ND <	0.46		NC
Molybdenum		83.0		37.9		23.1		48		31
Nickel		106		8.91		7.85		41		57
Selenium		131		427		259		272		148
Vanadium		1.66		2.78		1.13		1.9		0.84

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

NC = Not calculated.

= Outlier value, not used in calculations (Mn and K results believed to be from KMnO4 impinger solution).

Silicon value refers to probe rinse only.

Possible contamination of aluminum, potassium, and sodium in filter analysis.

Sample results corrected for train blank.

TABLE 5-6. ELEMENTS IN GAS SAMPLES FROM SCR REACTOR OUTLET (LOCATION 20) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-20-MUM-719		N-20-MUM-722		N-20-MUM-724		AVERAGE		DL RATIO	SD
Aluminum	3270	#	577		722		650			NC
Potassium	16000	#	325		258		291			NC
Silicon	11200	#	3190	ND <	13.9	#	NC			NC
Sodium	4840	#	1150		1070		1200			NC
Titanium	19.8	#	5.38		7.41		6.4			NC
Antimony	ND <	0.927	#	ND <	0.511	ND <	0.558	ND <	0.53	NC
Arsenic		4.95	#		2.44	ND <	0.558		1.4	10% NC
Barium		10.4	#		1.94		0.337		1.1	NC
Beryllium	ND <	0.194	#	ND <	0.168	ND <	0.219	ND <	0.19	NC
Boron		NA			NA		NA		NA	NA
Cadmium		1.31	#	ND <	0.168	ND <	0.219	ND <	0.19	NC
Chromium		51.7	#		5.98		7.92		7.0	NC
Cobalt		1.01	#	ND <	0.337	ND <	0.438	ND <	0.39	NC
Copper		55.5	#		21.4		12.6		17	NC
Lead		6.84	#	ND <	0.511	ND <	0.558	ND <	0.53	NC
Manganese		18800	#		3.42		13.2		8.3	NC
Mercury		35.8			29.0		27.6		31	4.4
Molybdenum		29.4	#		10.5		8.54		10	NC
Nickel		37.2	#		2.25		2.87		2.6	NC
Selenium		52.8	#		109		96.3		103	NC
Vanadium		1.22	#		0.709		0.467		0.59	NC

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

NC = Not calculated.

= Outlier value, not used in calculations (Mn and K values believed to be from KMnO_4 impinger solution).

Samples corrected for N-21-MUM-718 train blank.

Silicon not determined in cyclones and filter.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

TABLE 5-7. ELEMENTS IN PARTICULATE MATTER FROM WSA CONDENSER OUTLET (LOCATION 21) (µg/g)

Analyte	N-21-MUM-719		N-21-MUM-722		N-21-MUM-724		AVERAGE		DL RATIO	SD
Aluminum	7930	ND <	18.5 #		3260		5600			NC
Potassium	4450	ND <	70.2		878		1788		1 %	2344
Silicon	1610		1220		754		1190			428
Sodium	10500	ND <	1630		7140		6150		4 %	4918
Titanium	60.1	ND <	5.43		26.7		30		3 %	29
Antimony	ND <	12.7	ND <	24.2	ND <	16.2	ND <	18		5.9
Arsenic	ND <	12.7	ND <	24.2	ND <	16.2	ND <	18		5.9
Barium		9.80	ND <	3.51	ND <	2.40		4.3	23 %	4.8
Beryllium		3.03		5.43	ND <	3.88	ND <	3.9		1.8
Boron		NA		NA		NA		NA		NA
Cadmium		3.03	ND <	5.43	ND <	3.88	ND <	5.4		0.56
Chromium		35.9		2200 #		100		68		NC
Cobalt	ND <	6.07		33.1 #	ND <	7.76	ND <	6.9		NC
Copper		18.3		10.2		3.88		11		7.2
Lead	ND <	12.7	ND <	24.2		23.5	ND <	24		8.7
Manganese		11.7		163		14.3		63		86
Mercury		14.4		25.9		62.5		34		25
Molybdenum		112		286		101		166		104
Nickel		6.07		1000 #		86.4		46		NC
Selenium		15.6		11.5		8.89		12		3.4
Vanadium	ND <	3.03	ND <	5.43	ND <	3.88	ND <	4.1		1.2

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

NC = Not calculated.

= Outlier value, not used in calculations (chromium, cobalt, nickel, and possibly molybdenum values are believed to result from contamination by stainless steel).

Silicon value refers to probe rinse only.

Possible contamination of aluminum, potassium, and sodium in filter analysis.

Sample results corrected for train blank.

TABLE 5-8. ELEMENTS IN GAS SAMPLES FROM WSA CONDENSER OUTLET (LOCATION 21) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-21-MUM-719	N-21-MUM-722	N-21-MUM-724	AVERAGE	DL RATIO	SD
Aluminum	475	ND < 0.438 #	181	328		NC
Potassium	267	ND < 1.87	49.1	106	0%	142
Silicon	12.9	15.6	15.2	15		1.4
Sodium	652	ND < 52.7 #	421	536		NC
Titanium	3.62	ND < 0.136	1.50	1.7	1%	1.8
Antimony	ND < 0.637	ND < 0.683	ND < 0.750	ND < 0.69		0.057
Arsenic	ND < 0.637	ND < 0.683	ND < 0.750	ND < 0.69		0.057
Barium	0.609	ND < 0.094	ND < 0.105	0.24	14%	0.32
Beryllium	0.376	0.247	ND < 0.162	0.23	12%	0.15
Boron	NA	NA	NA	NA		NA
Cadmium	0.230	ND < 0.138	ND < 0.162	ND < 0.16		0.090
Chromium	4.29	72.8 #	6.47	5.4		NC
Cobalt	ND < 0.275	1.14 #	ND < 0.324	ND < 0.30		NC
Copper	1.48	1.38	0.785	1.2		0.38
Lead	ND < 0.637	ND < 0.683	1.53	0.73	30%	0.69
Manganese	2.45	5.60	2.85	3.6		1.7
Mercury	36.2	21.9	30.7	30		7.2
Molybdenum	6.90	9.64	5.88	7.5		1.9
Nickel	1.04	33.1 #	5.01	3.0		NC
Selenium	1.42	0.610	0.721	0.92		0.44
Vanadium	ND < 0.137	ND < 0.138	ND < 0.162	ND < 0.15		0.014

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

NC = Not calculated.

= Outlier value, not used in calculations (chromium and nickel values are believed to result from contamination by stainless steel).

Samples corrected for N-21-MUM-718 train blank.

Silicon not determined in cyclones and filter.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

TABLE 5-9. ELEMENTS IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

Analyte	TRAIN BLANK	
	N-21-MUM-718	
Aluminum		6810
Potassium		4310
Silicon		10500
Sodium		10500
Titanium		17.8
Antimony	ND <	0.575
Arsenic	ND <	0.575
Barium		15.9
Beryllium	ND <	0.110
Boron		NA
Cadmium	ND <	0.110
Chromium		0.695
Cobalt	ND <	0.219
Copper		3.75
Lead	ND <	0.575
Manganese		1.70
Mercury		0.251
Molybdenum		3.71
Nickel	ND <	0.219
Selenium		1.43
Vanadium	ND <	0.110

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

Silicon not determined in cyclones and filter.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

Train blank corrected for 0.1 N HNO₃ field reagent blank.

5.1.2 Solid Samples

Tables 5-10 through 5-12 present the results of analyses for elements in solid samples. Results are reported in units of $\mu\text{g/g}$. Data are presented for boiler feed coal (Location 1) by ICP-AES, GF-AAS and CV-AAS; SO_2 catalyst waste (Location 23), and baghouse ash (Location 24). In each table, the daily average sample composite results are shown along with the average and standard deviation of those results. The composite sample identification scheme and compositing procedures are described in Section 3.2.2

Results from the coal analysis round-robin study coordinated by Consol, Inc. for DOE/PETC are presented in Appendix B Auditing of this report.

TABLE 5-10. ELEMENTS IN BOILER FEED COAL (LOCATION 1) ($\mu\text{g/g}$)

Analyte	JL1993-BOFED	JL2293-BOFED	JL2493-BOFED	AVERAGE	DL RATIO	SD
Aluminum	14000	13300	13700	13700		351
Potassium	2100	1900	2100	2000		115
Silicon	24500	24400	25000	24600		321
Sodium	300	400	200	300		100
Titanium	800	700	800	767		58
Antimony	0.7	0.9	1.1	0.9		0.20
Arsenic	46	20	36	34		13
Barium	60	70	60	63		23
Beryllium	2.3	2.5	2.0	2.27		0.25
Boron	19	70	69	53		29
Cadmium	ND < 0.3	ND < 0.3	ND < 0.3	ND < 0.3		0
Chromium	15	17	14	15		1.5
Cobalt	5.9	5.3	5.0	5.4		0.46
Copper	14	15	12	14		1.5
Lead	14	11	14	13		1.7
Manganese	31	27	22	27		4.5
Mercury	0.33	0.27	0.17	0.26		0.081
Molybdenum	3.6	ND < 3	3.0	ND < 3		1.1
Nickel	14	16	16	15		1.2
Selenium	ND < 0.6	1.1	1.6	0.90	10%	0.66
Vanadium	25	29	24	26		2.6

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

TABLE 5-11. ELEMENTS IN SO₂ CATALYST WASTE (LOCATION 23) (μg/g)

<u>Analyte</u>		<u>N-23-PRS-723</u>
Aluminum		6700
Potassium		97800
Silicon		224000
Sodium		13000
Titanium		600
Antimony		7.7
Arsenic		10.0
Barium		45
Beryllium		9.4
Boron		130
Cadmium	ND <	2.0
Chromium		99
Cobalt		13
Copper		17
Lead	ND <	20
Manganese		130
Mercury	ND <	0.03
Molybdenum	ND <	40
Nickel		44
Selenium	ND <	4.0
Vanadium		110

ND < = Not detected, value following ND < is detection limit.

TABLE 5-12. ELEMENTS IN BAGHOUSE ASH (LOCATION 24) ($\mu\text{g/g}$)

Analyte	JL1993-BAGH	JL2293-BAGH	JL2493-BAGH	AVERAGE	DL RATIO	SD
Aluminum	105000	106000	94900	102000		6140
Potassium	24500	26200	29400	26700		2490
Silicon	177000	179000	164000	173000		8150
Sodium	3700	4000	14700	7470		6270
Titanium	7400	8300	6900	7530		709
Antimony	43	44	55	47		6.7
Arsenic	1120	1240	1190	1180		60
Barium	760	910	1000	890		121
Beryllium	38	39	41	39		1.5
Boron	700	820	750	757		60
Cadmium	2.00	ND <	2.00	2.00	ND <	0.58
Chromium	260	280	300	280		20
Cobalt	71	100	103	91		18
Copper	420	480	460	453		31
Lead	522	596	602	573		45
Manganese	270	280	270	273		5.8
Mercury	0.11	0.08	0.06	0.083		0.025
Molybdenum	85	130	130	115		26
Nickel	270	320	350	313		40
Selenium	7.00	8.50	9.40	8.3		1.2
Vanadium	410	450	470	443		31

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

5.1.3 Liquid Samples

Location 22, sulfuric acid process stream, was the only sampling location for liquids. Results of elemental analyses are shown in Table 5-13. The highest measured concentrations of elements in the sulfuric acid stream were boron (77 mg/L) and selenium (30 mg/L). The concentration ratio [boron]/[selenium] in the sulfuric acid was about 2.6 compared to a corresponding ratio of 59 in the boiler feed coal and 91 in the baghouse ash. Capture of selenium in the sulfuric acid stream (and enrichment relative to other elements) has been noted by ABB in other studies. As will be discussed in Section 6.1, the selenium concentration in the sulfuric acid constitutes a major flow of selenium in the process.

TABLE 5-13. ELEMENTS IN SULFURIC ACID (LOCATION 22) (mg/L)

Analyte	N-22-PRL-719		N-22-PRL-722		N-22-PRL-724		AVERAGE	DL RATIO	SD
Aluminum		15.9		12.6		12.3	14		2.0
Potassium		18.3		20.7		14.5	18		3.1
Silicon	ND <	1	ND <	1	ND <	1	ND <	1	0
Sodium		4.48		5.34		5.64	5.2		0.60
Titanium		0.63		0.607		0.53	0.59		0.052
Antimony	ND <	0.02	ND <	0.02	ND <	0.02	ND <	0.02	0
Arsenic		0.15		0.14		0.12	0.14		0.015
Barium		1.98		1.94		1.74	1.9		0.13
Beryllium	ND <	0.1	ND <	0.1	ND <	0.1	ND <	0.1	0
Boron		73.5		79.3		79.1	77		3.3
Cadmium	ND <	0.1	ND <	0.1	ND <	0.1	ND <	0.1	0
Chromium	ND <	0.1	ND <	0.1	ND <	0.1	ND <	0.1	0
Cobalt	ND <	0.200	ND <	0.200	ND <	0.200	ND <	0.20	0
Copper	ND <	0.1	ND <	0.1	ND <	0.1	ND <	0.1	0
Lead	ND <	0.02	ND <	0.02	ND <	0.02	ND <	0.02	0
Manganese		0.1		0.1	ND <	0.1	ND <	0.1	0.029
Mercury		0.09		0.14		0.14	0.12		0.029
Molybdenum		1.53	ND <	1	ND <	1	ND <	1	0.14
Nickel	ND <	0.2	ND <	0.2	ND <	0.2	ND <	0.2	11
Selenium		28		33		28	30		2.9
Vanadium	ND <	0.1	ND <	0.1	ND <	0.1	ND <	0.1	0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

5.2 Ammonia/Cyanide

Ammonia and cyanide were measured in four flue gas streams. Results are presented in Table 5-14 for the baghouse inlet (Location 18), Table 5-15 for the baghouse outlet (Location 19), Table 5-16 for the SCR reactor outlet (Location 20), and Table 5-17 for the WSA condenser outlet (Location 21). Results from analyses of blank samples are presented in Table 5-18.

On July 19, ABB injected ammonia into the SNOX process at a rate higher than normal for controlling NO_x (see the discussion of SNOX operating conditions in Section 2.3 and the discussion of problems during sampling in Section 3.2.4). The elevated ammonia concentrations at Location 20 on this date may reflect the higher rate of ammonia addition on this day.

ABB expects ammonia concentrations in the range 20-30 ppm (about 18,000-26,000 $\mu\text{g}/\text{Nm}^3$) at Location 20 under the elevated temperature conditions there. Assuming that these concentrations of NH_3 do exist in the flue gas, then NH_3 must have formed solid-phase sulfate compounds in the sampling equipment before it reached the impingers for collection. The measured sulfate concentrations of 195, 39, and 23 mg/Nm^3 are consistent with such a loss of ammonia during sampling. A loss of 20 ppm ammonia corresponds to about 46 mg/Nm^3 of sulfate in $(\text{NH}_4)_2\text{SO}_4$, somewhat more than the 39 and 23 mg/Nm^3 recorded on the two days with normal ammonia injection rates. The adverse sampling constraints at Location 20 coupled with the single point measurement make the comparison of ammonia loss and sulfate gain difficult.

TABLE 5-14. AMMONIA/CYANIDE IN GAS SAMPLES FROM BAGHOUSE INLET (LOCATION 18) ($\mu\text{g}/\text{Nm}^3$)

	N-18-NH3-719	N-18-NH3-722	N-18-NH3-724			
Analyte	N-18-CN-719	N-18-CN-722	N-18-CN-724	AVERAGE	DL RATIO	SD
Ammonia	202	91.7	254	183		83
Cyanide	493	410	402	435		51

DL Ratio = Detection limit ratio.

SD = Standard deviation.

Sample results corrected for train blank.

TABLE 5-15. AMMONIA/CYANIDE IN GAS SAMPLES FROM BAGHOUSE OUTLET (LOCATION 19) ($\mu\text{g}/\text{Nm}^3$)

	N-19-NH3-719	N-19-NH3-722	N-19-NH3-724			
Analyte	N-19-CN-719	N-19-CN-722	N-19-CN-724	AVERAGE	DL RATIO	SD
Ammonia	325	128	551	335		212
Cyanide	427	519	391	446		66

DL Ratio = Detection limit ratio.

SD = Standard deviation.

Sample results corrected for train blank.

TABLE 5-16. AMMONIA/CYANIDE IN GAS SAMPLES FROM SCR REACTOR OUTLET (LOCATION 20) ($\mu\text{g}/\text{Nm}^3$)

	N-20-NH4-719	N-20-NH4-722	N-20-NH4-724		
Analyte	N-20-CN-719	N-20-CN-722	N-20-CN-724	AVERAGE DL RATIO	SD
Ammonia *	313 **	15.5	18.3	116	171
Cyanide	184	267	428	293	124

DL Ratio = Detection limit ratio.

SD = Standard deviation.

Sample results corrected for train blank.

* Based upon operation of the SNOX process, ammonia concentrations of about 18,000 - 26,000 $\mu\text{g}/\text{Nm}^3$ could be expected at this location. The reported values are believed to reflect artifact loss of ammonia by formation of ammonium sulfate and ammonium bisulfate in the sampling equipment.

** Ammonia was injected into the SNOX process at a higher rate on July 19 than on other days.

TABLE 5-17. AMMONIA/CYANIDE IN GAS SAMPLES FROM WSA CONDENSER OUTLET (LOCATION 21) ($\mu\text{g}/\text{Nm}^3$)

	N-21-NH4-719	N-21-NH4-722	N-21-NH4-724			
<u>Analyte</u>	<u>N-21-CN-719</u>	<u>N-21-CN-722</u>	<u>N-21-CN-724</u>	<u>AVERAGE</u>	<u>DL RATIO</u>	<u>SD</u>
Ammonia	67.1	590 #	86.4	77		NC
Cyanide	181	198	269	216		47

DL Ratio = Detection limit ratio.

SD = Standard deviation.

= Outlier value, not used in calculations.

Sample results corrected for train blank.

TABLE 5-18. AMMONIA/CYANIDE IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

	TRAIN BLANK
	N-21-NH4-718
<u>Analyte</u>	<u>N-21-CN-718</u>
Ammonia	20.5
Cyanide	2.49

5.3 Anions

Anions were measured in four flue gas streams, two solid streams, and the one liquid process stream. Results are presented in three sections corresponding to the type of process stream.

5.3.1 Gas Samples

Tables 5-19 through 5-23 present results for anions in flue gas samples. Blank results are shown in Table 5-23. Table 5-19 contains results for the baghouse inlet (Location 18), and Table 5-20 contains results for the baghouse outlet (Location 19). Table 5-21 presents results for the SCR reactor outlet (Location 20), and Table 5-22 presents results for the WSA tower outlet (Location 21).

The data obtained at Location 20 (Table 5-21) show the effect of the high rate of injection of ammonia into the SNOX process on July 19 (see the discussion of SNOX operating conditions in Section 2.3, the discussion of problems during sampling in Section 3.2.4, and Table 5-22). On July 19, ABB delivered more ammonia into the SNOX process than was needed to control NO_x , and the filter in the sampling train became clogged after only about one hour of sampling, whereas on other days a filter could be used for over four hours before particulate matter built up on it and caused a substantial pressure drop across it. Late in the day on July 19, ABB reduced the injection rate of ammonia, and sampling continued without incident. Table 5-21 shows that the chloride and sulfate concentrations in the flue gas in particulate matter were much greater on July 19 than on July 22 or July 24. This is believed to be artifact formation in the sampling system as the ammonia rich sample stream was drawn through the probe and filter, and the temperature of the sample stream was reduced to about 121 K (250°F). Note that the acid gases, HCl and HF show more uniform concentrations for the three sampling days.

TABLE 5-19. ANIONS IN GAS SAMPLES FROM BAGHOUSE INLET (LOCATION 18) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-18-FCL-719	N-18-FCL-722	N-18-FCL-724	AVERAGE	DL RATIO	SD
Hydrogen Chloride	195000	177000	188000	187000		9070
Hydrogen Fluoride	9820	7960	10600	9460		1360
Chloride	0.59	ND <	13.6	27.0 ND <	14	14
Fluoride	227		150	184	187	38
Phosphate	12.2	ND <	3.40	ND <	5.2	22% 6.0
Sulfate	68500	58100	72100	66200		7270

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

TABLE 5-20. ANIONS IN GAS SAMPLES FROM BAGHOUSE OUTLET (LOCATION 19) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-19-FCL-719	N-19-FCL-722	N-19-FCL-724	AVERAGE	DL RATIO	SD
Hydrogen Chloride	168000	221000	265000	218000		48600
Hydrogen Fluoride	8230	10200	13200	10500		2500
Chloride	ND <	16.5	ND <	15.6	1.96 ND <	17 3.5
Fluoride		10.4		7.42	1.45	6.4 4.5
Phosphate	ND <	1.65	ND <	1.56	ND <	1.63 ND <
Sulfate		2520		7510	21000	10300 9560

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

TABLE 5-21. ANIONS IN GAS SAMPLES FROM SCR REACTOR OUTLET (LOCATION 20) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-20-FCL-719	N-20-FCL-722	N-20-FCL-724	AVERAGE	DL RATIO	SD
Hydrogen Chloride	202000	201000	195000	199000		3790
Hydrogen Fluoride	12800	7320	12200	10800		3010
Chloride	110 #	10.6	1.73	6.2		NC
Fluoride	13.8	1.79	6.82	7.5		6.0
Phosphate	ND < 88.6	ND < 1.54	ND < 1.50	ND < 31		50
Sulfate	195000 #	39000	23500	31200		NC

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

= Outlier value, not used in calculations.

Sample results corrected for train blank.

The chloride and sulfate data for July 19 are believed to be artifacts resulting from formation of particulate material in the sampling system as excess ammonia reacted with flue gases. The rate of injection of ammonia into the SNOX system was higher on July 19 than on July 22 or 24 (see Table 5-16).

TABLE 5-22. ANIONS IN GAS SAMPLES FROM WSA CONDENSER OUTLET (LOCATION 21) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-21-FCL-719	N-21-FCL-722	N-21-FCL-724	AVERAGE	DL RATIO	SD
Hydrogen Chloride	109000	137000	93700	113000		22000
Hydrogen Fluoride	9210	10100	8040	9120		1030
Chloride	6.60	ND <	16.7	87.2	34	46
Fluoride	610		5.80	28.6	215	343
Phosphate	4.74	ND <	1.67	ND <	5.52	ND <
Sulfate	62100	54000	118000	78000		34800

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

TABLE 5-23. ANIONS IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

Analyte	TRAIN BLANK
	N-21-FCL-718
Hydrogen Chloride	10.4
Hydrogen Fluoride	13.5
Chloride	16.1
Fluoride	1.24
Phosphate	1.73
Sulfate	45.4

5.3.2 Solid Samples

Results for anions in boiler feed coal (Location 1) are presented in Table 5-24.
Results for anions in baghouse ash (Location 24) are presented in Table 5-25.

TABLE 5-24. ANIONS IN BOILER FEED COAL (LOCATION 1) ($\mu\text{g/g}$)

Analyte	JL1993BOFED		JL2293BOFED		JL2493BOFED		AVERAGE	DL RATIO	SD
Fluoride		0.881		1.38		1.06		1.1	0.25
Chloride		3.46		5.63		2.51		3.9	1.6
Phosphate	ND <	1.00	ND <	1.00	ND <	1.00	ND <	1.0	0
Sulfate		NA		NA		NA			

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

TABLE 5-25. ANIONS IN BAGHOUSE ASH (LOCATION 24) ($\mu\text{g/g}$)

Analyte	JL1993BAGH		JL2293BAGH		JL2493BAGH		AVERAGE	DL RATIO	SD
Fluoride		22.0		16.7		10.5		16	5.8
Chloride		12.9		13.5		15.3		14	1.2
Phosphate	ND <	5.00	ND <	5.00	ND <	5.00	ND <	5.0	0
Sulfate		32000		31900		37700		33900	3320

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

5.3.3 Liquid Samples

Results for anions in sulfuric acid (Location 22) are presented in Table 5-26.

TABLE 5-26. ANIONS IN SULFURIC ACID (LOCATION 22) ($\mu\text{g/ml}$)

Analyte	N-22-PRL-719		N-22-PRL-722		N-22-PRL-724		AVERAGE	DL RATIO	SD
Chloride	NA		NA		NA				
Fluoride	NA		NA		NA				
Phosphate	ND <	10000	ND <	10000	ND <	10000	ND <	10000	0
Sulfate	*		*		*				

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

* = Sulfuric acid content confirmed to be 95 percent by weight by means of density measurement.

5.4 Volatile Organic Compounds

Volatile organic compounds (VOC) were measured only in flue gas streams at the SNOX process. Results are presented for Locations 18-21 in Tables 5-27 through 5-30. Each of the values reported in these tables is an average of the values from the three determinations made by the distributive volume collection approach that is used in the VOST collection protocol. Results for blank samples are shown in Table 5-31. These results were obtained from samples collected with a Volatile Organic Sampling Train (VOST). In Section 7, results obtained from samples collected in canisters are compared with the VOST results.

Referring to Table 5-31, methylene chloride (or dichloromethane) was used in the field to clean glassware. The high blank value of 2,100 $\mu\text{g}/\text{Nm}^3$ shown in this table is believed to be contamination of the blank with the solvent. The data in Tables 5-27 through 5-30 are not corrected for the train blank. Because of the contamination, an emission factor is not reported for methylene chloride in Section 6.

Acetone also shows high values in Tables 5-27 through 5-30 but not in the blank (Table 5-31). Acetone was used in the field to rinse the sampling probes in Method 29 trains and in the laboratory. Acetone was found in the laboratory blank. Consequently, an emission factor is not reported for acetone in Section 6.

Results are not reported for chloromethane at Locations 18, 19, and 20 because of a large interfering peak in the chromatogram. Data are reported for this compound at Location 21 in Table 5-30. The data exhibit considerable scatter. For example, the reported value of 99.8 $\mu\text{g}/\text{Nm}^3$ for July 23 is the average of three collections in the distributive volume sampling approach: 245, ND <5.6, and 54 $\mu\text{g}/\text{Nm}^3$.

TABLE 5-27. VOC IN GAS SAMPLES FROM BAGHOUSE INLET (LOCATION 18) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-18-VOS-718		N-18-VOS-721		N-18-VOS-723		AVERAGE	DL RATIO	SD
Chloromethane		I		I		I		NC	NC
Bromomethane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Vinyl Chloride	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Chloroethane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Methylene Chloride *		34.1		14.3		16.9		NC	NC
Acetone *		61.3		47.0		35.6		NC	NC
Carbon Disulfide		6.93		12.3		24.5		14.6	9.0
1,1-Dichloroethene	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
1,1-Dichloroethane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Trans-1,2-Dichloroethene	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Chloroform		2.98	ND <	4.70	ND <	4.58	ND <	4.7	0.38
1,2-Dichloroethane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
2-Butanone	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
1,1,1-Trichloroethane	ND <	5.42	ND <	4.70	ND <	4.58	ND <	4.9	0.46
Carbon Tetrachloride		2.80	ND <	4.70	ND <	4.58	ND <	4.7	0.28
Vinyl Acetate	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Bromodichloromethane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
1,2-Dichloropropane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
cis-1,3-Dichloropropylene	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Trichloroethene	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Dibromochloromethane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
1,1,2-Trichloroethane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Benzene		17.6		54.9		19.8		31	21
trans-1,3-Dichloropropylene	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
2-Chloroethylvinylether	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Bromoform	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
4-Methyl-2-Pentanone		3.99	ND <	4.70	ND <	4.58	ND <	4.7	0.96
2-Hexanone		7.75	ND <	4.70	ND <	4.58	ND <	4.7	3.1
Tetrachloroethene	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
1,1,2,2-Tetrachloroethane	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Toluene		8.39	ND <	4.70		2.80	ND <	4.7	3.4
Chlorobenzene	ND <	5.13	ND <	4.70	ND <	4.28	ND <	4.7	0.43
Ethylbenzene	ND <	5.42	ND <	4.70	ND <	4.58	ND <	4.9	0.46
Styrene	ND <	5.13	ND <	4.70	ND <	4.58	ND <	4.8	0.29
Xylenes (Total)		6.76	ND <	4.70	ND <	4.58	ND <	4.7	2.6

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NC = Not calculated.

I = Interference prevented detection/quantification of analyte concentration or detection limit.

Sample results corrected for train blank.

* Concentrations are believed to be artifacts resulting from contamination by these compounds used as solvents.

TABLE 5-28. VOC IN GAS SAMPLES FROM BAGHOUSE OUTLET (LOCATION 19) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-19-VOS-718		N-19-VOS-721		N-19-VOS-723		AVERAGE	DL RATIO	SD
Chloromethane		I		I		I		NC	NC
Bromomethane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Vinyl Chloride	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Chloroethane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Methylene Chloride *		495		29.6		138		NC	NC
Acetone *		86.3		59.9		36.6		NC	NC
Carbon Disulfide		3.87		3.03		5.09		3.4	1.0
1,1-Dichloroethene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
1,1-Dichloroethane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Trans-1,2-Dichloroethene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Chloroform	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
1,2-Dichloroethane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
2-Butanone	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
1,1,1-Trichloroethane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Carbon Tetrachloride	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Vinyl Acetate	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Bromodichloromethane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
1,2-Dichloropropane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
cis-1,3-Dichloropropylene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Trichloroethene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Dibromochloromethane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
1,1,2-Trichloroethane	ND <	11.3	ND <	5.78	ND <	9.78	ND <	8.9	2.8
Benzene		21.7		9.17		35.7		22	13
trans-1,3-Dichloropropylene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
2-Chloroethylvinylether	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Bromoform	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
4-Methyl-2-Pentanone	ND <	11.3	ND <	5.78	ND <	5.79	ND <	7.6	3.2
2-Hexanone		13.1		5.78		5.72		7.2	13% 5.3
Tetrachloroethene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
1,1,2,2-Tetrachloroethane	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Toluene		4.62		5.78		3.04		5.8	0.96
Chlorobenzene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Ethylbenzene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Styrene	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26
Xylenes (Total)	ND <	6.24	ND <	5.78	ND <	5.79	ND <	5.9	0.26

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NC = Not calculated.

I = Interference prevented detection/quantification of analyte concentration or detection limit.

Sample results corrected for train blank.

* Concentrations are believed to be artifacts resulting from contamination by these compounds used as solvents.

TABLE 5-29. VOC IN GAS SAMPLES FROM SCR REACTOR OUTLET (LOCATION 20) ($\mu\text{g}/\text{Nm}^3$)

Analyte		N-20-VOS-718	N-20-VOS-721	N-20-VOS-723	AVERAGE	DL RATIO	SD
Chloromethane		I	I	I	NC		NC
Bromomethane	ND <	6.40	6.76	71.3	26	4%	38
Vinyl Chloride	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Chloroethane	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Methylene Chloride *		75.1	20.3	29.0	NC		NC
Acetone *		67.7	20.4	15.8	NC		NC
Carbon Disulfide		5.02	ND <	13.7	ND <	14	1.6
1,1-Dichloroethene	ND <	6.40	ND <	7.34	ND <	7.0	0.49
1,1-Dichloroethane	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Trans-1,2-Dichloroethene	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Chloroform	ND <	6.40	ND <	7.34	ND <	7.0	0.49
1,2-Dichloroethane	ND <	6.40	ND <	7.34	ND <	7.0	0.49
2-Butanone	ND <	6.40	ND <	7.34	ND <	7.0	0.49
1,1,1-Trichloroethane	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Carbon Tetrachloride	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Vinyl Acetate	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Bromodichloromethane	ND <	6.40	ND <	7.34	ND <	7.0	0.49
1,2-Dichloropropane	ND <	6.40	ND <	7.34	ND <	7.0	0.49
cis-1,3-Dichloropropylene	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Trichloroethene	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Dibromochloromethane	ND <	6.40	ND <	7.34	ND <	7.0	0.49
1,1,2-Trichloroethane	ND <	6.40	6.14	ND <	7.13	ND <	7.1
Benzene		4.92	11.4	ND <	12.5	ND <	13
trans-1,3-Dichloropropylene	ND <	6.40	ND <	7.34	ND <	7.0	0.49
2-Chloroethylvinylether	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Bromoform	ND <	6.40	ND <	7.34	ND <	7.0	0.49
4-Methyl-2-Pentanone		15.6	16.2	ND <	7.13	12	10%
2-Hexanone		26.2	34.9	23.6	28		5.9
Tetrachloroethene	ND <	6.40	ND <	7.34	ND <	7.0	0.49
1,1,2,2-Tetrachloroethane	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Toluene		11.6	ND <	6.09	11.8	8.8	12%
Chlorobenzene	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Ethylbenzene	ND <	6.40	ND <	6.09	ND <	6.5	0.53
Styrene	ND <	6.40	ND <	7.34	ND <	7.0	0.49
Xylenes (Total)	ND <	6.40	ND <	7.34	ND <	7.0	0.49

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

NC = Not calculated.

I = Interference prevented detection/quantification of analyte concentration or detection limit.

Sample results corrected for train blank.

* Concentrations are believed to be artifacts resulting from contamination by these compounds used as solvents.

TABLE 5-30. VOC IN GAS SAMPLES FROM WSA CONDENSER OUTLET (LOCATION 21) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-21-VOS-718		N-21-VOS-721		N-21-VOS-723		AVERAGE	DL RATIO	SD
Chloromethane		592		204		99.8		299	259
Bromomethane	ND <	15.6		18.0		13.7	ND <	16	5.1
Vinyl Chloride	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Chloroethane	ND <	7.24	ND <	10.2		5.43	ND <	4.7	1.0
Methylene Chloride *		44.1		10.9		52.6		NC	NC
Acetone *		71.4		88.1		31.3		NC	NC
Carbon Disulfide	ND <	15.6	ND <	20.1		4.55	ND <	20	2.8
1,1-Dichloroethene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
1,1-Dichloroethane	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Trans-1,2-Dichloroethene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Chloroform	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
1,2-Dichloroethane	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
2-Butanone	ND <	7.24	ND <	20.1	ND <	6.69	ND <	11	7.6
1,1,1-Trichloroethane	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Carbon Tetrachloride	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Vinyl Acetate	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Bromodichloromethane	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
1,2-Dichloropropane	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
cis-1,3-Dichloropropylene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Trichloroethene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Dibromochloromethane	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
1,1,2-Trichloroethane	ND <	7.24		13.3	ND <	6.69	ND <	7.2	5.6
Benzene		4.97		8.20		9.86		7.7	2.5
trans-1,3-Dichloropropylene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
2-Chloroethylvinylether	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Bromoform	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
4-Methyl-2-Pentanone	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
2-Hexanone		16.2		57.2	ND <	6.69		26	28
Tetrachloroethene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
1,1,2,2-Tetrachloroethane	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Toluene		8.74	ND <	8.00		3.48	ND <	8.0	2.9
Chlorobenzene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Ethylbenzene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Styrene	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9
Xylenes (Total)	ND <	7.24	ND <	10.2	ND <	6.69	ND <	8.0	1.9

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for train blank.

* Concentrations are believed to be artifacts resulting from contamination by these compounds used as solvents.

TABLE 5-31. VOC IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-19-VOS-718	
Chloromethane	ND <	3.28
Bromomethane	ND <	3.28
Vinyl Chloride	ND <	3.28
Chloroethane	ND <	3.28
Methylene Chloride		2100
Acetone	ND <	3.28
Carbon Disulfide	ND <	3.28
1,1-Dichloroethene	ND <	3.28
1,1-Dichloroethane	ND <	3.28
Trans-1,2-Dichloroethene	ND <	3.28
Chloroform		1.57
1,2-Dichloroethane	ND <	3.28
2-Butanone	ND <	3.28
1,1,1-Trichloroethane		4.32
Carbon Tetrachloride	ND <	3.28
Vinyl Acetate	ND <	3.28
Bromodichloromethane	ND <	3.28
1,2-Dichloropropane	ND <	3.28
cis-1,3-Dichloropropylene	ND <	3.28
Trichloroethene	ND <	3.28
Dibromochloromethane	ND <	3.28
1,1,2-Trichloroethane	ND <	3.28
Benzene	ND <	3.28
trans-1,3-Dichloropropylene	ND <	3.28
2-Chloroethylvinylether	ND <	3.28
Bromoform	ND <	3.28
4-Methyl-2-Pentanone	ND <	3.28
2-Hexanone	ND <	3.28
Tetrachloroethene	ND <	3.28
1,1,2,2-Tetrachloroethane	ND <	3.28
Toluene	ND <	3.28
Chlorobenzene	ND <	3.28
Ethylbenzene	ND <	3.28
Styrene	ND <	3.28
Xylenes (Total)	ND <	3.28

ND < = Not detected, value following ND < is detection limit.

Methylene chloride results are believed to be contamination from the methylene chloride used as a solvent in the field.

Methylene chloride samples not corrected for methylene chloride train blank values.

5.5 PAH/SVOC

Polynuclear aromatic hydrocarbons (PAH) and other semi-volatile organic compounds (SVOC) were measured in gas and solid streams for the SNOX process. Results are presented in two sections corresponding to the two types of process streams.

5.5.1 Gas Samples

Results for PAH/SVOC in flue gas streams are presented in Tables 5-32 through 5-35. Results are shown for Locations 18-21. Results for blanks are presented in Table 5-36.

Samples of vapor and particulate phase PAH and SVOC were collected and analyzed separately. The results were added together according to DOE's protocol to calculate total values for each compound. In the footnotes to Tables 5-32 through 5-35, the volume of the extract for each vapor (called X for the XAD resin that collected the vapor) and particle phase (called F for the filter) sample is provided. Because of sample matrix effects (see Appendix F), the extracts for the vapor samples could be concentrated down to only 1,000 to 2,000 μl , whereas the extracts for the particle samples were concentrated down to 100 μl . The detection limits for the particle samples were in general much less than for the vapor samples. As a consequence, for many of the values reported as not detected in Tables 5-32 through 5-35, the compound was detected in the particle phase but in summing the particle concentration and one-half the detection limit of the vapor phase the total result was less than the detection limit for the vapor phase. Therefore the result could only be reported as the detection limit of the vapor phase component. Note that in Section 7.1, this specific protocol was not followed in order to evaluate the particle/vapor phase distribution of PAH and other SVOC.

TABLE 5-32. PAH/SVOC IN GAS SAMPLES FROM BAGHOUSE INLET (LOCATION 18) (ng/Nm³)

Analyte	N-18-MM5- F+X-718		N-18-MM5- F+X-721		N-18-MM5- F+X-723		AVERAGE	DL RATIO	SD	
Benzylchloride	ND <	17.2	ND <	19.8	ND <	18.4	ND <	18	1.3	
Acetophenone		657		850		301		603	279	
Hexachloroethane	ND <	17.2	ND <	19.8	ND <	18.4	ND <	18	1.3	
Naphthalene		485		311		132		309	176	
Hexachlorobutadiene	ND <	17.2	ND <	19.8	ND <	18.4	ND <	18	1.3	
2-Chloroacetophenone	ND <	17.2	ND <	19.8	ND <	18.4	ND <	18	1.3	
2-Methylnaphthalene		145		107		32.9		95	57	
1-Methylnaphthalene		76.8		51.1		17.9		49	30	
Hexachlorocyclopentadiene	ND <	17.2	ND <	19.8	ND <	18.4	ND <	18	1.3	
Biphenyl		224		162		24.2		136	102	
Acenaphthylene		32.1		15.9	ND <	3.67		17	4%	15
2,6-Dinitrotoluene		47.1	ND <	19.8		31.2		29	11%	19
Acenaphthene		57.0		78.9		23.1		53		28
Dibenzofuran		222		135		45.8		134		88
2,4-Dinitrotoluene		25.5		62.4	ND <	18.4		32	9%	27
Fluorene		182		91.6		17.0		97		83
Hexachlorobenzene	ND <	17.2	ND <	19.8	ND <	18.4	ND <	18		1.3
Pentachlorophenol	ND <	17.2	ND <	19.8	ND <	18.4	ND <	18		1.3
Phenanthrene		2470 E		783		197		1150		1180
Anthracene		178		41.4		9.64		76		89
Fluoranthene		4670 E		592		75.8		1780		2520
Pyrene		1360 E		166		24.0		517		734
Benz(a)anthracene		871		98.8		5.5		325		475
Chrysene		3020 E		405		42.0		1160		1620
Benzo(b & k)fluoranthene		539		91.5		11.4		214		284
Benzo(e)pyrene		89.9		16.8	ND <	3.7		36	2%	47
Benzo(a)pyrene		7.4	ND <	4.0	ND <	3.7	ND <	4.0		3.2
Indeno(1,2,3-c,d)pyrene	ND <	3.4	ND <	4.0	ND <	3.7	ND <	3.7		0.25
Dibenzo(a,h)anthracene	ND <	3.4	ND <	4.0	ND <	3.7	ND <	3.7		0.25
Benzo(g,h,i)perylene	ND <	3.4	ND <	4.0	ND <	3.7	ND <	3.7		0.25

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

The reported F+X data (ng/Nm³) are the sum of the corrected filter data and the corrected XAD-2 data. The corrected filter and XAD-2 data were obtained by dividing the corrected total amount (ng) with the corresponding sample volume (Nm³).

The field blanks used for the background correction are N-21-MM5-F-717, and N-21-MM5-X-717.

TABLE 5-33. PAH/SVOC IN GAS SAMPLES FROM BAGHOUSE OUTLET (LOCATION 19) (ng/Nm³)

Analyte	N-19-MM5- F+X-718	N-19-MM5- F+X-721	N-19-MM5- F+X-723	AVERAGE	DL RATIO	SD
Benzylchloride	ND < 8.83	ND < 18.9	ND < 9.49	ND < 12		5.6
Acetophenone	98.9	179	371	216		140
Hexachloroethane	ND < 8.83	ND < 18.9	ND < 9.49	ND < 12		5.6
Naphthalene	133	120	2.37	85		72
Hexachlorobutadiene	ND < 8.83	ND < 18.9	ND < 9.49	ND < 12		5.6
2-Chloroacetophenone	1300	34.7	ND < 9.49	446	0%	739
2-Methylnaphthalene	57.7	20.0	21.1	33		21
1-Methylnaphthalene	30.1	11.4	11.3	18		11
Hexachlorocyclopentadiene	ND < 8.83	ND < 18.9	ND < 9.5	ND < 12		5.6
Biphenyl	2710 E	523 E	88.7	1110		1400
Acenaphthylene	30.1	19.8	2.41	17		14
2,6-Dinitrotoluene	ND < 8.8	ND < 18.9	ND < 9.5	ND < 12		5.6
Acenaphthene	719	38.9	7.1	255		402
Dibenzofuran	208	258	64.9	177		100
2,4-Dinitrotoluene	10.8	43.5	10.8	22		19
Fluorene	66.6	55.0	5.38	42		32
Hexachlorobenzene	ND < 8.8	ND < 18.9	ND < 9.5	ND < 12		5.6
Pentachlorophenol	ND < 8.83	ND < 18.9	ND < 9.49	ND < 12		5.6
Phenanthrene	86.9	152	61.3	100		47
Anthracene	6.54	6.51	3.52	5.5		1.7
Fluoranthene	15.8	17.3	16.4	16		0.79
Pyrene	1.91	ND < 3.78	3.13	ND < 3.8		0.71
Benz(a)anthracene	3.80	12.9	2.81	6.5		5.6
Chrysene	2.96	10.5	12.0	8.5		4.8
Benzo(b & k)fluoranthene	ND < 1.77	8.38	6.02	5.1	6%	3.8
Benzo(e)pyrene	ND < 1.77	ND < 3.78	2.47	ND < 3.8		0.80
Benzo(a)pyrene	ND < 1.77	4.54	ND < 1.90	2.1	29%	2.1
Indeno(1,2,3-c,d)pyrene	4.03	3.80	1.90	3.2		1.2
Dibenzo(a,h)anthracene	ND < 1.77	ND < 3.78	ND < 1.90	ND < 2.5		1.1
Benzo(g,h,i)perylene	ND < 1.77	ND < 3.78	ND < 1.90	ND < 2.5		1.1

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

The reported F+X data (ng/Nm³) are the sum of the corrected filter data and the corrected XAD-2 data. The corrected filter and XAD-2 data were obtained by dividing the corrected total amount (ng) with the corresponding sample volume (Nm³). The field blanks used for the background correction are N-21-MM5-F-717, and N-21-MM5-X-717.

TABLE 5-34. PAH/SVOC IN GAS SAMPLES FROM SCR REACTOR OUTLET (LOCATION 20) (ng/Nm³)

Analyte	N-20-MM5- F+X-718	N-20-MM5- F+X-721	N-20-MM5- F+X-723	AVERAGE	DL RATIO	SD
Benzylchloride	ND < 1.13	ND < 25.4	ND < 25.4	ND < 17		14
Acetophenone	ND < 1.13	412	474	296	0%	257
Hexachloroethane	ND < 1.13	ND < 25.4	ND < 25.4	ND < 17		14
Naphthalene	4.00	49.2	76.9	43		37
Hexachlorobutadiene	ND < 1.13	ND < 25.4	ND < 25.4	ND < 17		14
2-Chloroacetophenone	ND < 1.13	55.8	ND < 25.4	25	19%	28
2-Methylnaphthalene	2.89	32.1	19.3	18		15
1-Methylnaphthalene	2.89	17.5	12.6	11		7.5
Hexachlorocyclopentadiene	ND < 1.13	ND < 25.4	ND < 25.4	ND < 17		14
Biphenyl	248 E	1310 E	89.3 E	549		664
Acenaphthylene	ND < 0.23	ND < 5.09	ND < 5.09	ND < 3.5		2.8
2,6-Dinitrotoluene	66.9	ND < 25.4	ND < 25.4	31	28%	31
Acenaphthene	ND < 0.23	16.6	11.5	9.4	0%	8.4
Dibenzofuran	7.25	59.6	ND < 25.4	27	16%	29
2,4-Dinitrotoluene	1.84	67.2	ND < 25.4	27	16%	35
Fluorene	2.11	14.4	ND < 5.1	6.4	13%	7.0
Hexachlorobenzene	ND < 1.13	ND < 25.4	ND < 25.4	ND < 17		14
Pentachlorophenol	ND < 1.13	ND < 25.4	ND < 25.4	ND < 17		14
Phenanthrene	ND < 0.23	85.4	51.9	46	0%	43
Anthracene	0.59	7.5	ND < 5.09	5.1	24%	3.5
Fluoranthene	ND < 0.23	26.4	21.0	16	0%	14
Pyrene	1.03	6.03	ND < 5.09	ND < 5.1		2.6
Benz(a)anthracene	ND < 0.23	ND < 5.09	ND < 5.09	ND < 3.5		2.8
Chrysene	3.14	17.1	8.23	9.5		7.1
Benzo(b & k)fluoranthene	9.96	31.0	7.59	16		13
Benzo(e)pyrene	2.79	13.2	ND < 5.09	6.2	14%	6.1
Benzo(a)pyrene	0.63	ND < 5.09	ND < 5.09	ND < 5.1		1.1
Indeno(1,2,3-c,d)pyrene	1.51	ND < 5.09	9.28	5.1	19%	4.2
Dibenzo(a,h)anthracene	3.31	ND < 5.09	ND < 5.09	ND < 5.1		0.44
Benzo(g,h,i)perylene	2.64	ND < 5.09	ND < 5.09	ND < 5.1		0.05

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

The reported F+X data (ng/Nm³) are the sum of the corrected filter data and the corrected XAD-2 data. The corrected filter and XAD-2 data were obtained by dividing the corrected total amount (ng) with the corresponding sample volume (Nm³). The field blanks used for the background correction are N-21-MM5-F-717, and N-21-MM5-X-717.

Average and standard deviation includes only N-20-MM5-F+X-721 and N-20-MM5-F+X-723 because of loss of sample N-20-MM5-X-718 during the sample preparation process. Note that data reported on N-20-MM5-F+X-718 only includes includes results for sample N-20-MM5-F-718.

TABLE 5-35. PAH/SVOC IN GAS SAMPLES FROM WSA CONDENSER OUTLET (LOCATION 21) (ng/Nm³)

Analyte	N-21-MM5- F+X-718	N-21-MM5- F+X-721	N-21-MM5- F+X-723	AVERAGE	DL RATIO	SD
Benzylchloride	2.43	96.7	ND < 9.97	35	5 %	54
Acetophenone	145 E	472	627	415		246
Hexachloroethane	ND < 1.04	ND < 11.5	ND < 9.97	ND < 7.5		5.7
Naphthalene	85.3 E	113	47.4	82		33
Hexachlorobutadiene	ND < 1.04	ND < 11.5	ND < 9.97	ND < 7.5		5.7
2-Chloroacetophenone	ND < 1.04	ND < 11.5	ND < 9.97	ND < 7.5		5.7
2-Methylnaphthalene	14.4	55.2	12.3	27		24
1-Methylnaphthalene	8.14	30.6	8.32	16		13
Hexachlorocyclopentadiene	ND < 1.04	ND < 11.5	ND < 9.97	ND < 7.5		5.7
Biphenyl	19.6	3.94	ND < 1.99	8.2	4 %	10
Acenaphthylene	2.90	10.6	3.63	5.7		4.3
2,6-Dinitrotoluene	ND < 1.04	ND < 11.5	ND < 9.97	ND < 7.5		5.7
Acenaphthene	7.60	11.5	2.92	7.3		4.3
Dibenzofuran	17.4	24.0	13.7	18		5.2
2,4-Dinitrotoluene	4.98	ND < 11.5	ND < 9.97	ND < 12		0.45
Fluorene	0.33	ND < 2.30	ND < 1.99	ND < 2.3		0.44
Hexachlorobenzene	ND < 1.04	ND < 11.5	ND < 9.97	ND < 7.5		5.7
Pentachlorophenol	2.43	ND < 11.5	ND < 9.97	ND < 12		1.7
Phenanthrene	50.3 E	27.6	21.7	33		15
Anthracene	2.11	7.70	4.94	4.9		2.8
Fluoranthene	13.5	8.51	6.28	9.4		3.7
Pyrene	0.61	3.40	ND < 1.99	ND < 2.0		1.5
Benz(a)anthracene	2.77	2.77	3.29	2.9		0.30
Chrysene	4.33	ND < 2.30	3.31	2.9	13 %	1.6
Benzo(b & k)fluoranthene	6.60	4.34	5.14	5.4		1.1
Benzo(e)pyrene	2.49	ND < 2.30	ND < 1.99	ND < 2.3		0.82
Benzo(a)pyrene	1.73	ND < 2.30	ND < 1.99	ND < 2.3		0.39
Indeno(1,2,3-c,d)pyrene	2.04	ND < 2.30	ND < 1.99	ND < 2.3		0.56
Dibenzo(a,h)anthracene	0.76	ND < 2.30	ND < 1.99	ND < 2.3		0.20
Benzo(g,h,i)perylene	1.70	ND < 2.30	ND < 1.99	ND < 2.3		0.37

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

The reported F+X data (ng/Nm³) are the sum of the corrected filter data and the corrected XAD-2 data. The corrected filter and XAD-2 data were obtained by dividing the corrected total amount (ng) with the corresponding sample volume (Nm³). The field blanks used for the background correction are N-21-MM5-F-717, and N-21-MM5-X-717.

TABLE 5-36. PAH/SVOC IN BLANK GAS SAMPLES (ng/Nm³)

Analyte	N-21-MM5- F-717		N-21-MM5- X-717		TRAIN BLANK N-21-MM5- F+X-717	
Benzylchloride	ND <	2.11	ND <	21.1	ND <	21.1
Acetophenone		11.2		116		127
Hexachloroethane	ND <	2.11	ND <	21.1	ND <	21.1
Naphthalene		1.14		176		178
Hexachlorobutadiene	ND <	2.11	ND <	21.1	ND <	21.1
2-Chloroacetophenone	ND <	2.11		1070		1070
2-Methylnaphthalene		0.946	ND <	4.23	ND <	4.23
1-Methylnaphthalene		0.524	ND <	4.23	ND <	4.23
Hexachlorocyclopentadiene	ND <	2.11	ND <	21.1	ND <	21.1
Biphenyl		0.751		8.12		8.87
Acenaphthylene	ND <	0.423	ND <	4.23	ND <	4.23
2,6-Dinitrotoluene		20.5		1100		1120
Acenaphthene		0.905	ND <	4.23	ND <	4.23
Dibenzofuran	ND <	2.11	ND <	21.1	ND <	21.1
2,4-Dinitrotoluene	ND <	2.11	ND <	21.1	ND <	21.1
Fluorene		1.64		16.4		18.1
Hexachlorobenzene	ND <	2.11	ND <	21.1	ND <	21.1
Pentachlorophenol	ND <	2.11	ND <	21.1	ND <	21.1
Phenanthrene		4.17		11.3		15.4
Anthracene	ND <	0.423	ND <	4.23	ND <	4.23
Fluoranthene		1.81		5.76		7.57
Pyrene		0.658		4.79		5.45
Benz(a)anthracene	ND <	0.423	ND <	4.23	ND <	4.23
Chrysene		0.571	ND <	4.23	ND <	4.23
Benzo(b & k)fluoranthene	ND <	0.423	ND <	4.23	ND <	4.23
Benzo(e)pyrene	ND <	0.423	ND <	4.23	ND <	4.23
Benzo(a)pyrene	ND <	0.423	ND <	4.23	ND <	4.23
Indeno(1,2,3-c,d)pyrene	ND <	0.423	ND <	4.23	ND <	4.23
Dibenzo(a,h)anthracene	ND <	0.423	ND <	4.23	ND <	4.23
Benzo(g,h,i)perylene	ND <	0.423	ND <	4.23	ND <	4.23

ND < = Not detected, value following ND < is detection limit.

5.5.2 Solid Samples

Results for PAH and other SVOC in baghouse ash (Location 24) are shown in Table 5-37. This is the only solid process stream for which these determinations were made.

TABLE 5-37. PAH/SVOC IN BAGHOUSE ASH (LOCATION 24) (ng/g)

Analyte	JL1893BAGH	JL2193BAGH	JL2393BAGH	AVERAGE	DL RATIO	SD
Benzylchloride	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Acetophenone	0.651	0.602	1.71	0.99		0.62
Hexachloroethane	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Naphthalene	2.51	1.12	1.76	1.8		0.70
Hexachlorobutadiene	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
2-Chloroacetophenone	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
2-Methylnaphthalene	3.91	0.877	1.36	2.0		1.6
1-Methylnaphthalene	2.47	0.532	0.732	1.2		1.1
Hexachlorocyclopentadiene	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Biphenyl	0.584	0.324	1.60	0.84		0.67
Acenaphthylene	0.333	ND < 0.05	0.151	0.17	5%	0.15
2,6-Dinitrotoluene	1.23	1.41	2.70	1.8		0.80
Acenaphthene	0.285	0.121	0.274	0.23		0.09
Dibenzofuran	1.88	1.41	2.31	1.9		0.45
2,4-Dinitrotoluene	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Fluorene	1.68	0.752	1.38	1.3		0.47
Hexachlorobenzene	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Pentachlorophenol	ND < 0.25	ND < 0.25	ND < 0.25	ND < 0.25		0
Phenanthrene	2.55	0.849	1.09	1.5		0.92
Anthracene	0.575	0.111	0.139	0.28		0.26
Fluoranthene	0.637	0.341	0.315	0.43		0.18
Pyrene	0.464	0.174	0.168	0.27		0.17
Benz(a)anthracene	0.225	ND < 0.05	ND < 0.05	0.09	18%	0.12
Chrysene	0.338	0.053	0.065	0.15		0.16
Benzo(b & k)fluoranthene	0.203	0.052	ND < 0.05	0.09	9%	0.10
Benzo(e)pyrene	0.193	ND < 0.05	ND < 0.05	0.08	21%	0.10
Benzo(a)pyrene	0.147	ND < 0.05	ND < 0.05	0.07	25%	0.07
Indeno(1,2,3-c,d)pyrene	0.064	ND < 0.05	ND < 0.05	ND < 0.05		0.02
Dibenzo(a,h)anthracene	0.054	ND < 0.05	ND < 0.05	ND < 0.05		0.02
Benzo(g,h,i)perylene	0.132	ND < 0.05	ND < 0.05	0.06	27%	0.06

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

5.6 Aldehydes

Aldehydes were measured in four flue gas streams: Locations 18-21. Results are shown in Tables 5-38 through 5-41. Results of analysis of blank gas samples are shown in Table 5-42.

Considerable variation was observed in the measured aldehyde levels, most notably for acetaldehyde at the SCR outlet (Location 20 - Table 5-40). Difficulties in sampling at that location have been described in Section 3.2.4. Review of the field sampling log sheets did not indicate a problem with the aldehyde sampling that could explain the variability in reported concentrations.

TABLE 5-38. ALDEHYDES IN GAS SAMPLES FROM BAGHOUSE INLET (LOCATION 18) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-18-ALD-718		N-18-ALD-721		N-18-ALD-723		AVERAGE	DL RATIO	SD
Formaldehyde	14.5		ND <	2.34	ND <	2.12	5.6	13%	7.7
Acetaldehyde	61.9			29.1		11.6	34		26
Acrolein	ND <	2.27		21.1		1.35 J	7.8	5%	11
Propionaldehyde	3.40			38.3		1.62 J	14		21

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

J = Concentration detected below calibration range.

The DNPH solution for sample N-18-ALD-721 was light in color when received.

Sample results corrected for N-21-ALD-717 train blank.

TABLE 5-39. ALDEHYDES IN GAS SAMPLES FROM BAGHOUSE OUTLET (LOCATION 19) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-19-ALD-718		N-19-ALD-721		N-19-ALD-723		AVERAGE	DL RATIO	SD
Formaldehyde	ND <	2.39	ND <	2.31	ND <	2.27	ND <	2.3	0.06
Acetaldehyde		5.79		95.0		24.6		42	47
Acrolein	ND <	2.39		4.99		4.75	3.6	11%	2.1
Propionaldehyde	ND <	2.39		9.25		25.7	12	3%	13

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

The DNPH solution for samples N-19-ALD-718 and N-19-ALD-721 was light in color when received.

Sample results corrected for N-21-ALD-717 train blank.

TABLE 5-40. ALDEHYDES IN GAS SAMPLES FROM SCR REACTOR OUTLET (LOCATION 20) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-20-ALD-721	N-20-ALD-723-1	N-20-ALD-723-2	AVERAGE	DL RATIO	SD
Formaldehyde	4.80	22.2	5.40	10.8		9.9
Acetaldehyde	17.4	742	60.4	273		406
Acrolein	4.58	11.0	1.88 J	5.8		4.7
Propionaldehyde	25.5	14.7	1.62 J	14		12

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

J = Concentration detected below calibration range.

Sample results corrected for N-21-ALD-717 train blank.

TABLE 5-41. ALDEHYDES IN GAS SAMPLES FROM WSA CONDENSER OUTLET (LOCATION 21) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-21-ALD-721	N-21-ALD-723-1	N-21-ALD-723-2	AVERAGE	DL RATIO	SD
Formaldehyde	72.3	73.4	87.2	78		8.3
Acetaldehyde	556	534	503	531		27
Acrolein	12.0	8.94	13.5	11		2.3
Propionaldehyde	35.2	11.8	9.39	19		14

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND < = Not detected, value following ND < is detection limit.

Sample results corrected for N-21-ALD-717 train blank.

TABLE 5-42. ALDEHYDES IN BLANK GAS SAMPLES ($\mu\text{g}/\text{Nm}^3$)

Analyte	TRAIN BLANK N-21-ALD-717	DNPH BLANK N-18-ALD-717	DNPH BLANK N-18-ALD-RB
Formaldehyde	2.34 J	ND < 2.72	2.60 J
Acetaldehyde	1.88 J	ND < 2.72	ND < 2.72
Acrolein	ND < 2.72	ND < 2.72	ND < 2.72
Propionaldehyde	ND < 2.72	ND < 2.72	ND < 2.72

ND < = Not detected, value following ND < is detection limit.

J = Concentration detected below calibration range.

Sample and blank data corrected for average areas in DNPH Blank N-18-ALD-717 and DNPH Blank N-18-ALD-RB.

5.7 Radionuclides

Activity of radionuclides was measured in gas and solid streams. These results are presented in two sections.

5.7.1 Gas Samples

Results of measurements of radionuclides in flue gas streams are shown in Tables 5-43 through 5-46. These data were collected at Locations 18-21. Results of measurements on blank gas samples are shown in Table 5-47.

TABLE 5-43. RADIONUCLIDES IN GAS SAMPLES FROM BAGHOUSE INLET (LOCATION 18) (pCi/Nm³)

Analyte	N-18-NH4CN-719		N-18-NH4CN-722		N-18-NH4CN-724		AVERAGE	DL RATIO	SD
Pb-212	ND<	40.0	ND<	41.7	ND<	31.0	ND<	38	5.8
Th-234	ND<	400	ND<	295	ND<	477	ND<	391	92
Pb-210	ND<	560	ND<	589	ND<	668	ND<	606	56
Pb-211	ND<	773	ND<	638	ND<	644	ND<	685	76
Ra-226	ND<	64.0	ND<	51.6	ND<	64.4	ND<	60	7.3
Ra-228	ND<	152	ND<	123	ND<	138	ND<	138	15
Th-229	ND<	293	ND<	295	ND<	262	ND<	283	18
Th-230	ND<	3200	ND<	2950	ND<	2620	ND<	2923	291
U-234	ND<	11700	ND<	12500	ND<	11200	ND<	11800	656
U-235	ND<	125	ND<	128	ND<	117	ND<	123	5.7

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

TABLE 5-44. RADIONUCLIDES IN GAS SAMPLES FROM BAGHOUSE OUTLET (LOCATION 19) (pCi/Nm³)

Analyte	N-19-NH ₄ CN-719		N-19-NH ₄ CN-722		N-19-NH ₄ CN-724		AVERAGE	DL RATIO	SD
Pb-212	ND<	47.8	ND<	47.6	ND<	44.6	ND< 47	28%	1.8
Th-234	ND<	352		1130	ND<	520	522		409
Pb-210	ND<	528	ND<	503	ND<	545	ND< 525		21
Pb-211	ND<	629	ND<	715	ND<	668	ND< 671		43
Ra-226	ND<	52.8	ND<	58.2	ND<	56.9	ND< 56		2.8
Ra-228	ND<	138	ND<	140	ND<	136	ND< 138		2.1
Th-229	ND<	277	ND<	257	ND<	297	ND< 277		20
Th-230	ND<	2770	ND<	2910	ND<	3220	ND< 2970		230
U-234	ND<	12100	ND<	13500	ND<	12900	ND< 12800		702
U-235	ND<	128	ND<	127	ND<	126	ND< 127		1.0

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

TABLE 5-45. RADIONUCLIDES IN GAS SAMPLES FROM SCR REACTOR OUTLET (LOCATION 20) (pCi/Nm³)

Analyte	N-20-NH ₄ CN-719		N-20-NH ₄ CN-722		N-20-NH ₄ CN-724		AVERAGE	DL RATIO	SD
Pb-212	ND<	33.5	ND<	20.3	ND<	28.5	ND< 27	29%	6.7
Th-234	ND<	264		608	ND<	225	284		281
Pb-210	ND<	282		354	ND<	285	ND< 285		123
Pb-211	ND<	511	ND<	324	ND<	434	ND< 423		94
Ra-226	ND<	45.8	ND<	32.4	ND<	30.0	ND< 36		8.5
Ra-228	ND<	106	ND<	67.6	ND<	71.9	ND< 82		21
Th-229	ND<	211	ND<	149	ND<	150	ND< 170		36
Th-230	ND<	1940	ND<	1490	ND<	1650	ND< 1690		228
U-234	ND<	7570	ND<	6350	ND<	7790	ND< 7240		776
U-235	ND<	82.8	ND<	67.6	ND<	76.4	ND< 76		7.6

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

TABLE 5-46. RADIONUCLIDES IN GAS SAMPLES FROM WSA CONDENSER OUTLET (LOCATION 21) (pCi/Nm³)

Analyte	N-21-NH ₄ CN-719	N-21-NH ₄ CN-722	N-21-NH ₄ CN-724	AVERAGE	DL RATIO	SD
Pb-212	ND< 16.1	ND< 20.1	ND< 39.1	ND< 25		12
Th-234	186	ND< 167	ND< 309	ND< 309		53
Pb-210	ND< 200	ND< 167	ND< 494	ND< 287		180
Pb-211	ND< 300	ND< 268	ND< 515	ND< 361		134
Ra-226	ND< 28.3	ND< 28.5	ND< 49.4	ND< 35		12
Ra-228	ND< 71.6	ND< 61.9	ND< 111	ND< 82		26
Th-229	ND< 128	ND< 127	ND< 202	ND< 152		43
Th-230	ND< 1220	ND< 1240	ND< 2470	ND< 1640		716
U-234	ND< 4330	ND< 4850	ND< 10300	ND< 6490		3310
U-235	ND< 48.3	ND< 536	ND< 101	ND< 228		268

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

Sample results corrected for train blank.

TABLE 5-47. RADIONUCLIDES IN BLANK GAS SAMPLES (pCi/Nm³)

Analyte	TRAIN BLANK N-21-NH ₄ CN-718
Pb-212	ND< 25.8
Th-234	ND< 397
Pb-210	ND< 417
Pb-211	ND< 437
Ra-226	ND< 57.6
Ra-228	ND< 97.4
Th-229	ND< 219
Th-230	ND< 2190
U-234	ND< 9740
U-235	55.8

ND< = Not detected, value following ND< is detection limit.

5.7.2 Solid Samples

Radionuclides were measured in two solid streams. Results are shown for boiler feed coal (Location 1) in Table 5-48 and for SNOX baghouse ash (Location 24) in Table 5-49.

TABLE 5-48. RADIONUCLIDES IN BOILER FEED COAL (LOCATION 1) (pCi/g)

Analyte	JL1993BOFED	JL2293BOFED	JL2493BOFED	AVERAGE	DL RATIO	SD
Pb-210	1.99	1.62	2.42	2.0		0.40
Pb-212	0.265	0.299	0.29	0.28		0.017
Ra-226	0.482	0.414	0.59	0.50		0.089
Ra-228	ND< 0.52	ND< 0.26	ND< 0.28	ND< 0.35		0.14
Th-234	ND< 2.66	3.61	2.54	ND< 2.7		1.1
Pb-211	ND< 2.2	ND< 1.5	ND< 1.7	ND< 1.8		0.36
Th-229	ND< 0.8	ND< 0.66	ND< 0.69	ND< 0.72		0.074
Th-230	ND< 8.7	ND< 6.7	ND< 5.9	ND< 7.1		1.4
U-234	27.7	ND< 29	ND< 24	ND< 29		8.4
U-235	ND< 64	ND< 0.26	ND< 0.25	ND< 22		37

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

TABLE 5-49. RADIONUCLIDES IN BAGHOUSE ASH (LOCATION 24) (pCi/g)

Analyte	JL1993BAGH	JL2293BAGH	JL2493BAGH	AVERAGE	DL RATIO	SD
Pb-210	23.6	28.8	22.4	25		3.4
Pb-212	2.59	2.93	2.70	2.7		0.18
Ra-226	6.44	7.56	6.65	6.9		0.60
Ra-228	2.93	2.80	3.02	2.9		0.11
Th-234	12.2	12.1	10.5	12		0.95
Pb-211	ND< 2.55	ND< 2.60	ND< 2.00	ND< 2.4		0.33
Th-229	ND< 1.10	ND< 1.10	ND< 1.00	ND< 1.1		0.058
Th-230	ND< 14.0	ND< 13.0	ND< 12.0	ND< 13		1.0
U-234	72.3	62.5	33.7	56		20
U-235	0.754	0.615	0.575	0.65		0.094

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

5.8 Carbon Analyses

Carbon content of particulate matter in flue gas samples and in baghouse ash was measured and is reported in this section.

5.8.1 Gas Samples

Results of carbon determinations in particulate matter flue gas samples are shown in Table 5-50. The average carbon content of particulate matter in flue gas ahead of the baghouse was 3.0 percent. Following the baghouse, the carbon content was less than about 0.03 percent in particulate matter. The relatively low average value of 0.01 percent at Location 20 reflects the relatively high particle mass concentration that was measured at this location.

TABLE 5-50. CARBON IN FLUE GAS PARTICULATE SAMPLES (weight % dry)

Location	7/19	7/22	7/24	AVERAGE	DL RATIO	SD
18	4.65	2.75	1.56	3.0		1.6
19	ND< 0.00 C	0.04	0.05	0.03		0.026
20	0.01	ND< 0.00 C	0.02	0.01		0.010
21	0.06	0.04	ND< 0.00 C	0.033		0.031

DL Ratio = Detection limit ratio.

SD = Standard deviation.

ND< = Not detected, value following ND< is detection limit.

C = Sample result 0 or negative after correction for train blank;

detection limit not available so no contribution for detection limit in average.

Sample results corrected for N-21-NH₄CN-718 train blank.

5.8.2 Solid Samples

Results of carbon determinations are shown in Table 5-51 for dry baghouse ash (Location 24). The average carbon content of 8.1 percent is enriched compared to the average carbon content 3.0 of the particulate matter in the flue gas entering the baghouse.

TABLE 5-51. CARBON IN BAGHOUSE ASH (LOCATION 24) (% by weight, dry basis)

Analyte	JL1993BAGH	JL2293BAGH	JL2493BAGH	AVERAGE	DL RATIO	SD
Carbon	10.6	7.36	6.31	8.1		2.2

DL Ratio = Detection limit ratio.

SD = Standard deviation.

5.9 Ultimate/Proximate and Related Solid Sample Analyses

Results from ultimate and proximate analyses of boiler feed coal (Location 1) are shown in Table 5-52.

TABLE 5-52. ULTIMATE/PROXIMATE RESULTS FOR BOILER FEED COAL (LOCATION 1)

Analyte	JL1993BOFED	JL2293BOFED	JL2493BOFED	AVERAGE	DL RATIO	SD
Proximate Analysis (as received), percent						
Moisture	6.15	5.97	5.63	5.9		0.26
Ash	11.0	10.9	10.9	11		0.07
Volatile matter	33.8	34.3	34.7	34		0.43
Fixed Carbon (diff) *	49.0	48.9	48.8	49		0.11
Sulfur	2.51	2.40	2.52	2.5		0.07
Ultimate Analysis (dry), percent						
Carbon	72.3	71.9	72.6	72		0.34
Hydrogen	4.89	4.84	4.79	4.8		0.05
Nitrogen	1.50	1.48	1.47	1.5		0.02
Sulfur	2.67	2.55	2.67	2.6		0.07
Ash	11.7	11.6	11.5	12		0.10
Oxygen (diff) *	6.93	7.64	6.95	7.2		0.40
Heating Value, Btu/lb						
As received	12249	12218	12306	12258		45
Dry	13052	12994	13040	13029		31
MAF	14781	14692	14736	14736		45

DL Ratio = Detection limit ratio.

SD = Standard deviation.

MAF = Moisture and ash free.

* diff = Calculated by difference.

5.10 Particulate Size Distribution

The particle size distribution of baghouse ash is shown in Table 5-53. Two types of analysis were employed to yield the single cumulative distribution of particle mass by size. Screen sieves were used for the particle diameter range greater than 40 μm . This technique provides areal classification of particle diameter. For particle diameter less than about 40 μm , a Coulter counter was used, which provides volumetric classification of particles to determine their diameters.

The size distribution of suspended particulate matter in flue gas at the SNOX was measured in two different ways. At Locations 18 and 19, the inlet and outlet of the baghouse, respectively, cascade impactors were used to determine the particle size distribution. At Location 18, glass cyclones of 10 μm and 5 μm size cuts were also used upstream of the particulate filter in the Multi-Metals (Method 29) train. Size distribution measurements were made at Location 18 with both methods on all three inorganic sampling days (i.e., July 19, 22, and 24). At Location 19 an impactor sample was taken on July 19, but visual inspection of the exposed impactor stages revealed no visible loading of particulate matter on any stage. This finding is due to the high collection efficiency of the baghouse, and the consequent low particulate loading at Location 19. To assure adequate measurement of particle size distribution at Location 19, new impactor stages were installed, and were used in sampling every day from July 21 through 24. This approach was an attempt to build up particulate loading on the impactor stages, to improve the validity of the size distribution measurement.

Table 5-54 shows the impactor size distribution data from Location 18, the baghouse inlet. Impactors measure aerodynamic particle size. Shown in this table are the impactor stage designations, the size cuts for each stage in each sample run, the percent of particulate mass collected in each stage, and the cumulative percent of the mass collected in successive stages. Also shown is the average and standard deviation of the percent of particulate mass collected in each stage. Table 5-54 shows that the impactor size cuts were reproducible over the three runs, and that the measured particle size distribution was consistent. The particulate matter in the flue gas at this location was relatively coarse: 40 percent of the particulate mass was in particles greater than 8 μm in size, and over 70 percent was greater than 4 μm . Figure 5-1 shows a plot of the size distribution data.

As a quality assurance check, the total particulate loading determined by Method 29 sampling at Location 18 was compared to that inferred from the sum of particulate mass collected on the several impactor stages. It must be noted that these two approaches are markedly different. Method 29 used isokinetic multi-point sampling over several hours in both vertical and horizontal traverses of the duct; sample volumes were 5 to 6 Nm³. In contrast, the impactor runs at Location 18 were isokinetic samples of 5 minutes or less duration at a single point in the duct; sample volumes were 0.03 to 0.06 Nm³. The comparison of the total loadings determined by the two methods is shown below. These results show that the impactor loading values are about two-thirds of the Method 29 results. Given the very different durations and approaches of the methods, this degree of agreement is considered satisfactory.

Flue Gas Particulate Loading Measured at Location 18 (mg/Nm³)

<u>Date</u>	<u>Method 29</u>	<u>Impactor</u>
7/19/93	2,213	1,372
7/22/93	2,019	1,649
7/24/93	2,265	1,296

Table 5-55 shows the impactor size distribution data from Location 19, the baghouse outlet. The data are plotted in Figure 5-2. As noted above, these results come from two distinctly different sample runs. The impactor sampling on July 19 produced very little collected mass on the impactor stages, but represents a single sampling day. The impactor sampling that occurred on July 21-24 produced greater loading on the impactor stages, but was spread over four days, in which significant changes in the flue gas particulate matter may have occurred. For example, the flue gas particulate loading measured at Location 19 was 3.0 mg/Nm³ on July 19 and 6.0 mg/Nm³ on July 22, but was 40.7 mg/Nm³ on July 24. Nevertheless, the two impactor runs produced similar results for the particle size distribution, indicating that about 50 percent of the particulate mass at this location is in particles larger than about 3.5 μ m in diameter. Note that because only two runs were made, no standard deviation is shown in Table 5-56 for the percent mass collected by stage. The distribution at Location 19 (Table 5-55) is similar to that at Location 18 (Table 5-54), with a shift toward smaller particle sizes.

Comparison of total particulate loadings determined by Method 29 and by the impactor was also conducted for the data from Location 19. The differences between these methods noted above apply to sampling at Location 19 as well, with the exception that impactor sampling at Location 19 was conducted over extended time periods due to the low particulate loading at that location. The July 19 impactor run was for 2 hours with a sample volume of 1.76 Nm³. The July 21-24 impactor run was for a total of 12 hours with a sample volume of 8.67 Nm³. The comparison of Method 29 and impactor loading results from Location 19 is shown below, and indicates close agreement for the loading on July 19. The July 21-24 impactor result is lower than either the July 22 or July 24 Method 29 result, but is a credible value for Location 19, downstream of the baghouse. The comparability of Method 29 and impactor data for the second impactor run is questionable, because of the poor correspondence of the sampling periods. The impactor data do suggest that the value of 40.7 mg/Nm³ obtained by Method 29 on July 24 is unusual for Location 19.

Flue Gas Particulate Loading Measured at Location 19 (mg/Nm³)

<u>Date</u>	<u>Method 29</u>	<u>Impactor</u>
7/19/93	3.0	2.44
7/22/93	6.0	
7/24/93	40.7	0.93 (July 21-24)

The fractional collection efficiency of the SNOX baghouse filter was calculated as a function of particle size using the impactor data. The difference in the air volumes sampled for the baghouse inlet and outlet measurements were taken into account in calculating the efficiency. The average mass values collected by the impactor were used. The calculated results are shown in Figure 5-3. It is seen that the fractional efficiency ranges from 97 percent for 0.2 μm particles to higher than 99.9 percent for 8 μm particles indicating that the inertial impaction and interception mechanisms appear to control particle removal.

Table 5-56 shows the particle size distribution data from the cyclones and filter at Location 18. The sampling constraints at this location required a length of flexible heated line connecting the sampling probe to the cyclones. Because the combined probe and flexible line may collect some flue gas particles, the mass of particulate matter recovered in

the rinse of the probe and line is shown in Table 5-56 as a particulate fraction. Although the probe and flexible line are expected to collect primarily coarse particles, the size fraction of the probe rinse particulate matter is considered here to be undefined. Table 5-56 shows that about half of the particulate matter was removed in the probe and flexible line, and that less than 20 percent of the particulate matter was found at particle sizes smaller than 5 μm . These results are consistent with the more detailed size distribution data from the impactor sampling at Location 18, shown in Table 5-54.

TABLE 5-53. PARTICULATE SIZE DISTRIBUTION OF BAGHOUSE ASH (LOCATION 24)
(cumulative percent mass less than the size)

Micron Size	JL1993BAGH	JL2293BAGH	JL2493BAGH	Average	SD
Screen Analysis	106	93.7	94.4	94.8	94.3
	75	88.8	90.2	90.5	89.8
	45	80.2	79.00	37.6	65.6
					24.3
Coulter Counter	40.30	79.3	78.49	37.28	65.02
	32.00	78.4	77.71	36.96	64.36
	25.40	76.26	73.91	36.34	62.17
	20.20	69.57	70.15	35.54	58.42
	16.00	63.69	65.5	33.5	54.23
	12.70	54.29	57.76	29.6	47.22
	10.08	43.69	47.86	23.82	38.46
	8.00	32.14	36.32	18.23	28.90
	6.35	19.79	24.45	12.05	18.76
	5.05	9.77	12.73	6.38	9.63
	4.00	3.47	4.43	2.21	3.37
	3.17	0.63	0.5	1.07	0.73
	2.52	0.23	0.07	0.46	0.25
	2.00	0.21	0.04	0.40	0.22
	1.00	0	0	0	0
					0.56
					0.91
					24.3
					24.0
					23.7
					22.4
					19.8
					18.0
					15.4
					12.8
					9.47
					6.26
					3.18
					1.11
					0.30
					0.20
					0.18
					0.00

SD = Standard deviation.

TABLE 5-54. PARTICULATE SIZE DISTRIBUTION (IMPACTOR) AT BAGHOUSE INLET (LOCATION 18)

Impactor Stage	Sampling Day									
	July 19			July 22			July 24			Average % Mass by Stage (Std. Dev.)
	Cut $D_{50}^{(b)}$ (μm)	% Mass	Cumulative % Mass	Cut $D_{50}^{(b)}$ (μm)	% Mass	Cumulative % Mass	Cut $D_{50}^{(b)}$ (μm)	% Mass	Cumulative % Mass	
RAPC ^(a)	7.96	45.21	54.79	8.07	41.17	58.83	8.32	37.38	62.62	41.25 (3.92)
3	3.98	28.08	26.71	4.04	33.88	24.95	4.17	32.38	30.24	31.45 (3.01)
4	2.11	15.48	11.23	2.14	14.94	10.01	2.24	15.48	14.76	15.30 (0.31)
5	1.21	6.71	4.52	1.23	5.83	4.18	1.29	7.14	7.62	6.56 (0.67)
6	0.58	1.64	2.88	0.59	1.64	2.54	0.63	2.86	4.76	2.05 (0.70)
7	0.20	0.41	2.47	0.21	0.18	2.36	0.23	1.43	3.33	0.67 (0.67)
Filter		2.47	0		2.37	0		3.33	0	2.72 (0.53)

(a) Right angle pre-collector.

(b) Aerodynamic particle diameter.

TABLE 5-55. PARTICULATE SIZE DISTRIBUTION (IMPACTOR) AT BAGHOUSE OUTLET (LOCATION 19)

Impactor Stage	Sampling Days						Average % Mass by Stage
	July 19			July 21-24			
	Cut D ₅₀ ^(b) (μm)	% Mass	Cumulative % Mass	Cut D ₅₀ ^(b) (μm)	% Mass	Cumulative % Mass	
RAPC ^(a)	6.71	20.93	79.09	7.58	32.10	67.9	26.52
3	3.32	25.58	53.49	3.75	27.16	40.74	26.37
4	1.683	6.98	46.51	1.91	11.11	29.63	9.04
5	0.92	9.30	37.21	1.06	7.41	22.22	8.36
6	0.41	13.95	23.26	0.48	8.64	13.58	11.30
7	0.12	11.63	11.63	0.14	8.64	5.94	10.13
Filter		11.63	0		4.94	0	8.29

(a) Right angle pre-collector.

(b) Aerodynamic particle diameter.

TABLE 5-56. PARTICULATE SIZE DISTRIBUTION DATA (CYCLONES) AT BAGHOUSE INLET (LOCATION 18)

Particulate Fraction	Sampling Day						Average Percent Mass (Std. Dev.)
	July 19		July 22		July 24		
	Mass (g)	Fraction (%)	Mass (g)	Fraction (%)	Mass (g)	Fraction (%)	
Probe Wash	3.8197	32.5	6.1687	62.4	6.0946	51.1	48.7 (15.1)
> 10 $\mu\text{m}^{(a)}$	0.9076	7.7	1.2768	12.9	3.0593	25.7	15.4 (9.3)
5-10 $\mu\text{m}^{(b)}$	5.0158	42.6	0.5113	5.2	0.7588	6.4	18.1 (21.3)
< 5 $\mu\text{m}^{(c)}$	2.0216	17.2	1.9228	19.5	2.0039	16.8	17.8 (1.5)
Total	11.7647	100.0	9.8796	100.0	11.9166	100.0	

(a) From coarse cyclone (10 μm cut).(b) From fine cyclone (5 μm cut).

(c) From filter.

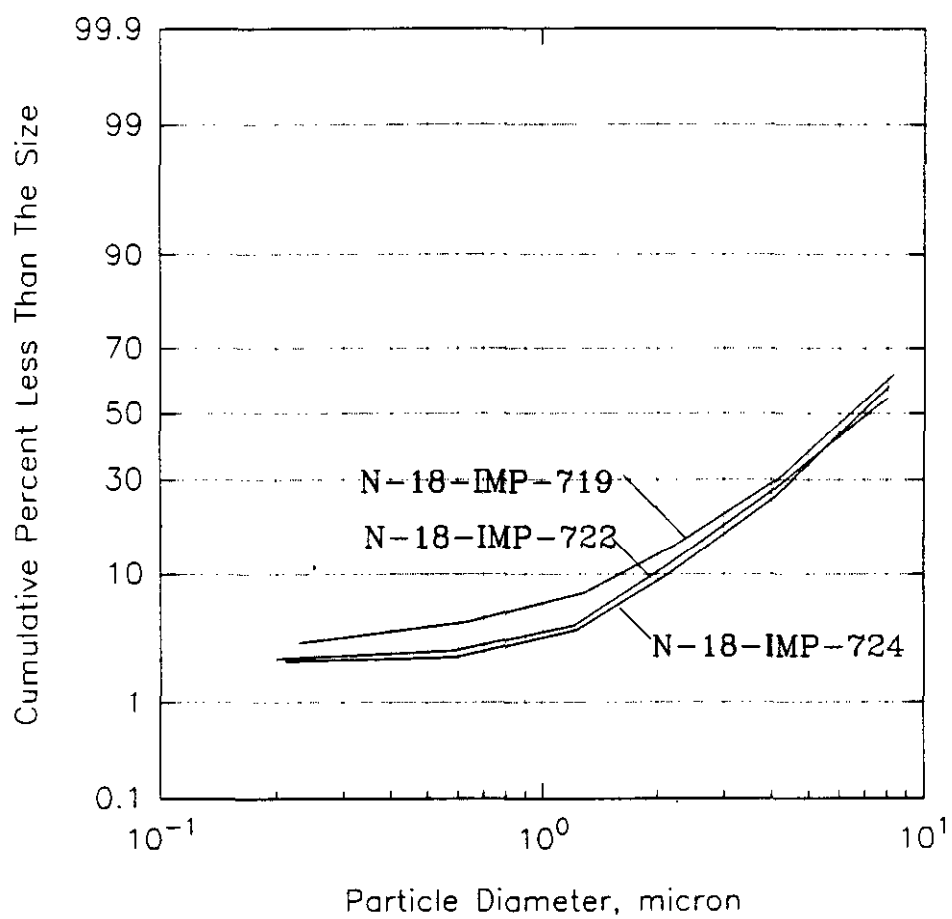


Figure 5-1. Cumulative size distribution measured at the inlet to the SNOX baghouse.

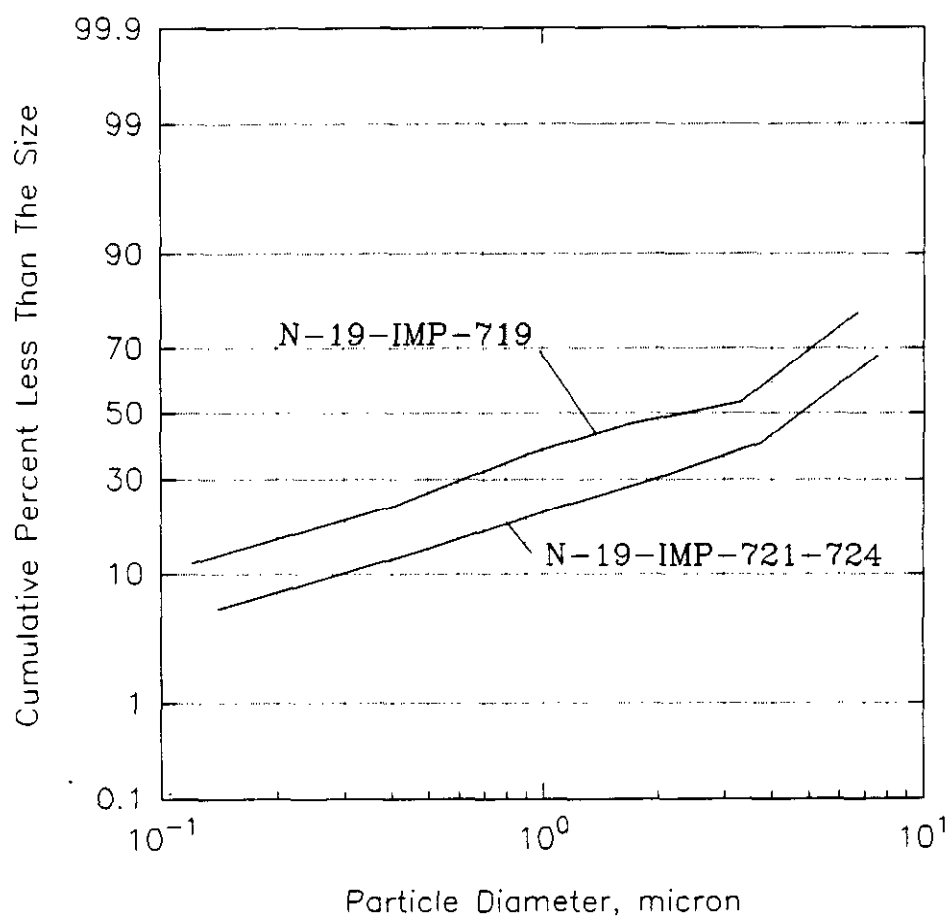


Figure 5-2. Cumulative size distribution measured at the outlet to the SNOX baghouse.

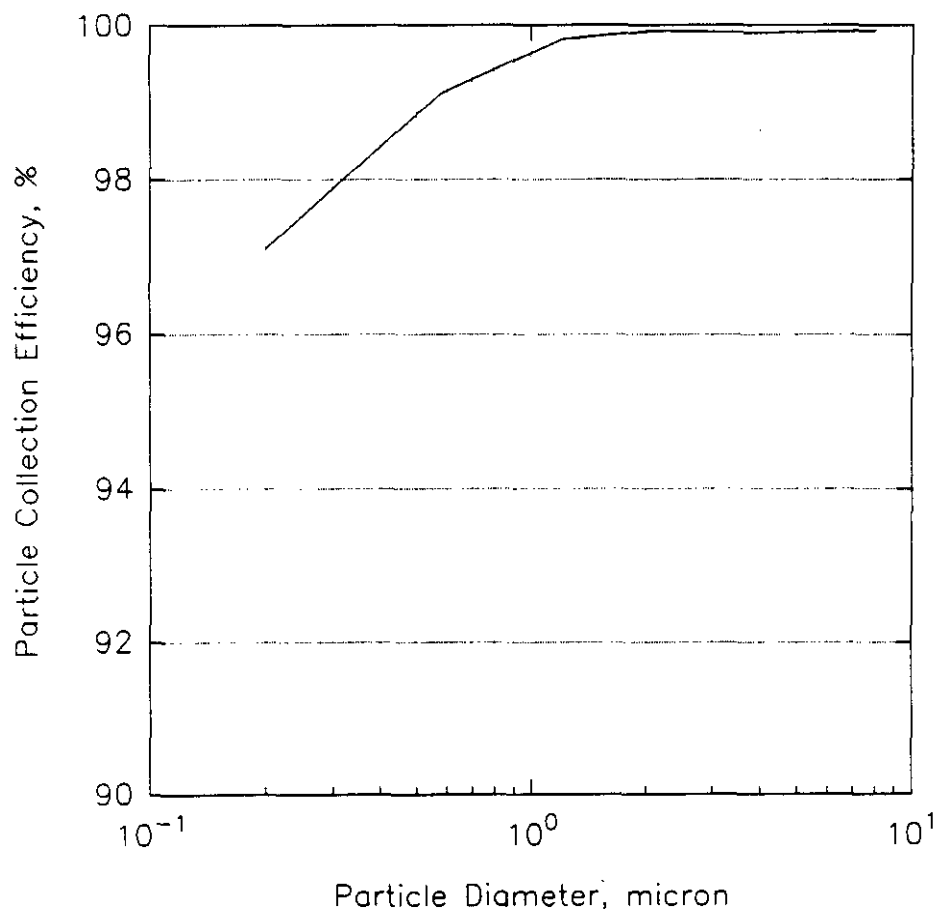


Figure 5-3. Fractional efficiency curve for SNOX baghouse removal of particulate matter.

6.0 DATA ANALYSIS AND INTERPRETATION

To meet the objectives of the U.S. DOE and U.S. EPA in fulfilling Congress' requirement for a study of emissions of HAPs from the electric utility industry, three types of calculations were performed on the data obtained for the SNOX process. Material balances were calculated for elements for the SNOX baghouse, SCR reactor, combined SO₂ reactor and WSA condenser, and entire SNOX system. These calculations provide information on the consistency of measurements of elements at the various sampling locations. Emission factors were calculated for all types of substances that were measured. This information will be used by the U.S. EPA in evaluating the emissions levels of HAPs from coal-fired power plants. Finally, removal efficiencies were calculated for elements. This information will be used by the U.S. DOE to evaluate the efficacy of advanced pollution control technologies.

6.1 Material Balances for Elements

The material balance calculations for elements are presented in three parts. First the assumptions that were made in performing the calculations are summarized. Then the results of the calculations are presented for each element. Finally, a short discussion of the calculations is provided.

6.1.1 Material Balance Calculations

Assumptions necessary for calculating material balances for elements were identical to those required for the ash material balances (Section 3). However:

- *Consistent with instructions from DOE regarding the occurrence of "less than" values in the results of the element analysis, a value equal to one-half of the detection limit was used in the element material balance calculations when less than values were reported.*

- Outliers in elemental concentrations (which are identified in Section 5 tables) were replaced with the average value from the remaining sampling days. All elemental concentrations determined on July 19 at Location 20 are considered to be outliers. Other outliers are identified in the discussion for the particular element.

Table 6-1 shows the material balance calculations for the one of the 21 elements of interest, aluminum. Material balances for each of the elements were performed in the same way, using a separate but identical spreadsheet for each element. Separate material balance calculations are shown for the baghouse, the SCR reactor, the SO₂ reactor and condenser together, and the overall SNOX system. These four systems are identified in Figures 6-1 and 6-2. The comments column gives details regarding the calculations.

The inlet and outlet streams for each system are listed below along with the sampling location in parentheses:

<u>System</u>	<u>Inlet Streams</u>	<u>Outlet Streams</u>
Baghouse	Flue gas (18)	Flue gas (19) Baghouse catch (24)
SCR Reactor	Flue gas (19)	Flue gas (20)
SO ₂ Reactor- WSA Condenser	Flue gas (20)	Flue gas (21) SO ₂ reactor waste (23) Sulfuric acid (22)
SNOX Process	Flue gas (18)	Flue gas (21) Baghouse catch (24) SO ₂ reactor waste (23) Sulfuric acid (22)

6.1.2 Material Balance Results

Table 6-2 shows the results of the material balance calculations for the 21 elements of interest. Figures 6-3 through 6-23 show the mass flow rate of elements in the inlet and

outlet streams for each of the four material balance systems. In Table 6-2, the material balances are expressed as the total output of material for all streams as a percentage of the total input of material. A value of 100 percent shows that an exact material balance was achieved. In some cases, the average value does not include one or more of the reported values for a specific element. This is noted in the table and discussed in the text.

For each element, separate material balance results are shown for the baghouse, the SCR reactor, the SO₂ reactor and condenser, and the overall SNOX system. Only the material balance results for the baghouse and the overall SNOX system are discussed in detail. As can be seen from the results, the material balances for the SCR reactor and for the SO₂ reactor and WSA condenser were poor. Material balances across the SCR reactor and the SO₂ removal system involved low concentrations for most elements because of the high removal efficiency of the baghouse. Accurate concentration measurements at low concentrations are difficult, and hence the material balances were poor. Additionally, the concentrations of most elements measured at Location 20 were much too high, resulting in material balances across the SCR that were much greater than 100 percent and material balances across the SO₂ reactor and WSA condenser that were much lower than 100 percent. The questionable data from Location 20 are attributed to the poor sampling conditions at that location. In particular the results for July 19 yielded what are believed to be unrealistically high concentrations for several elements. Sampling problems pertaining to particulate matter on this day were discussed in Section 3. As a result, the reported material balances for the SCR reactor and for the combined SO₂ reactor and WSA condenser are not discussed or reported in summary tables for all elements except mercury which was essentially all in the vapor phase.

Nevertheless, the results of the material balance calculations are shown for those cases where results are very poor and are the consequence of questionable data. This is done because the material balance calculations are diagnostic in character. That is, they show the level of consistency between measurements at various locations in the SNOX process. The following paragraphs summarize the results for each element.

Aluminum. The aluminum content of the two streams exiting the baghouse equalled 118 to 190 percent (average 142 percent) of the measured aluminum content of the flue gas

stream entering the baghouse. The relatively high value for closure of the material balance on the baghouse for July 19 resulted from the relatively low concentration of aluminum in the inlet stream on that day (about 123,000 $\mu\text{g}/\text{Nm}^3$ compared to about 180,000 $\mu\text{g}/\text{Nm}^3$ on the other two days).

The closure on the material balances for the SCR reactor system and the combined SO_2 reactor and WSA condenser shows poorer results than for the baghouse. This problem is present for several elements for these two systems, and the material balance closures for these two systems, in general, are not commented on for the other elements.

Considering the overall SNOX system, the aluminum content of the four streams exiting the system equalled 118 to 190 percent (average 142 percent) of the aluminum content of the flue gas stream entering the SNOX system.

Because the reported concentration of aluminum at Location 21 on July 22 (second day) was labelled an outlier (Table 5-8), the average value from July 19 and 24 was used in its place to calculate the material balance for July 22.

Potassium. The potassium content of the two streams exiting the baghouse equalled 111 to 142 percent (average 129 percent) of the measured potassium content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the potassium content of the four streams exiting the system equalled 111 to 141 percent (average 129 percent) of the potassium content of the flue gas stream entering the SNOX system.

Titanium. The titanium content of the two streams exiting the baghouse equalled 102 to 115 percent (average 110 percent) of the measured titanium content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the titanium content of the four streams exiting the system equalled 102 to 115 percent (average 110 percent) of the titanium content of the flue gas stream entering the SNOX system.

Silicon. A complete material balance could not be performed for silicon because the silicon content of some components of the sampling train (the cyclone and the filter catch)

were not analyzed for silicon. A material balance was performed using the available sampling train data; the results are subject to error.

Based on the portions of the sampling train that were analyzed for silicon, the silicon content of the two streams exiting the baghouse equalled 156 to 203 percent (average 175 percent) of the silicon content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the silicon content of the four streams exiting the system equalled 154 to 201 percent (average 174 percent) of the silicon content of the flue gas stream entering the SNOX system.

These results for silicon are consistent with the streams that control the material balance. For both the baghouse and the total SNOX process, the two streams that control the closure of the material balance are the inlet to the baghouse and the baghouse catch. The reported concentrations of silicon in the inlet stream was artificially depleted because the filter and cyclones could not be analyzed for silicon by the subcontractor laboratory. In contrast, the baghouse catch was not artificially depleted in silicon, and therefore the high closures reported in Table 6-2 are consistent with this line of reasoning.

The reported silicon concentration for July 24 at Location 20 was labelled as an outlier. Because the reported concentration for July 19 (along with all other elemental data except mercury) at this location was also considered suspect, only the data from July 22 for silicon were used in calculating material balances for silicon.

Sodium. The sodium content of the two streams exiting the baghouse equalled 158 to 504 percent (average 294 percent) of the measured sodium content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the sodium content of the four streams exiting the system equalled 167 to 479 percent (average 286 percent) of the sodium content of the flue gas stream entering the SNOX system. These results for the overall SNOX system track the reported closures for the baghouse. For both systems, the relatively low reported concentration of sodium in the inlet stream to the baghouse forced the closure on sodium to be high. For example, the ratio of concentrations of sodium to potassium in the feed coal and baghouse catch was about 1/7; whereas the concentration ratio in the fly ash at Location 18 was only about 1/10.

The reported concentrations of sodium for July 22 at Locations 19 and 21 were labelled as outliers (Tables 5-4 and 5-8). Therefore the average values for July 19 and 24 were used for these locations (except for Location 20 on July 19).

Mercury. The mercury content of the two streams exiting the baghouse equalled 83 to 137 percent (average 106 percent) of the measured mercury content of the flue gas stream entering the baghouse.

Note that the closure results for mercury for the SCR reactor system and the combined SO₂ reactor and WSA condenser system are quite consistent for the three days in contrast to the results for the other elements which generally show marked differences between the closures for July 19 and the other two days. A likely explanation is that mercury was almost entirely in the vapor phase whereas the other elements were predominantly in the solid phase. Problems reported in Section 3 with the particle filters at this location on July 19 caused the solid phase data to be suspect on this day at Location 20.

Considering the overall SNOX system, the mercury content of the four streams exiting the system equalled 91 to 152 percent (average 118 percent) of the mercury content of the flue gas stream entering the SNOX system.

Selenium. The selenium content of the two streams exiting the baghouse equalled 80 to 126 percent (average 100 percent) of the measured selenium content of the flue gas stream entering the baghouse.

The reported closure on selenium for the combined system of the SO₂ reactor and WSA condenser is about 270 percent for the second and third days. This result is driven by high concentration of selenium found in the sulfuric acid stream. This carries over to the material balance closure for the entire SNOX system.

Considering the overall SNOX system, the selenium content of the four streams exiting the system equalled 242 to 343 percent (average 287 percent) of the selenium content of the flue gas stream entering the SNOX system.

Arsenic. The arsenic content of the two streams exiting the baghouse equalled 63 to 89 percent (average 80 percent) of the measured arsenic content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the arsenic content of the four streams exiting the system equalled 63 to 89 percent (average 80 percent) of the arsenic content of the flue gas stream entering the SNOX system.

Cadmium. The cadmium content of the two streams exiting the baghouse equalled 41 to 81 percent (average 52 percent) of the measured cadmium content of the flue gas stream entering the baghouse. Note that the shaded portion of the table for cadmium illustrates that cadmium concentrations in the flue gas exiting the baghouse are reported as below the detection limit. One-half the detection limit was used for these calculations for the flue gas outlet stream.

Considering the overall SNOX system, the cadmium content of the four streams exiting the system equalled 40 to 99 percent (average 62 percent) of the cadmium content of the flue gas stream entering the SNOX system.

Chromium. The chromium content of the two streams exiting the baghouse equalled 88 to 118 percent (average 101 percent) of the measured chromium content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the chromium content of the four streams exiting the system equalled 88 to 118 percent (average 102 percent) of the chromium content of the flue gas stream entering the SNOX system.

The reported concentration of chromium for July 24 at Location 19 was labelled as an outlier (Table 5-4). Therefore the average of the reported concentrations for July 19 and 22 was used in its place to calculate a material balance. The reported concentration for July 22 at Location 21 was labelled as an outlier (Table 5-8). Therefore the average concentration for July 19 and 24 was used in its place to compute a material balance for chromium across the condenser and the SNOX system for July 22.

Molybdenum. The molybdenum content of the two streams exiting the baghouse equalled 52 to 141 percent (average 103 percent) of the measured molybdenum content of the flue gas stream entering the baghouse. The relatively high reported concentration of molybdenum in the inlet stream to the baghouse on July 19 ($367 \mu\text{g}/\text{Nm}^3$ compared to 229 and $207 \mu\text{g}/\text{Nm}^3$ on the other two days) produced the relatively low material balance closure for that day (52 percent compared to 116 and 141 percent on the other two days). At the same time, the argument could be made that the closure for the third day is about as high as the closure for the first day is low.

Considering the overall SNOX system, the molybdenum content of the four streams exiting the system equalled 57 to 121 percent (average 108 percent) of the molybdenum content of the flue gas stream entering the SNOX system.

Boron. A material balance could not be performed for boron because the flue gas samples were not analyzed for boron. However, referring to Figure 6-8, the mass flow of boron into the SNOX process is estimated to have been 0.63 kg/hr based upon the fraction of flue gas treated by the SNOX system. Fourteen percent of this left the process in the baghouse catch and sulfuric acid streams. The remainder is presumed to have been emitted out the stack.

Antimony. Only at the inlet to the baghouse are the antimony concentrations in the flue gas reported as above the detection limits. The relatively good closure on the material balance for the baghouse (110 percent with a standard deviation of 23 percent) is evidence that compared to the reported concentrations of antimony in the inlet stream to the baghouse, the use of one-half the detection limit for the remainder of the flue gas streams throughout the SNOX system is a relatively good approximation to the concentration of antimony in the flue gas. The antimony content of the two streams exiting the baghouse equalled 89 to 135 percent (average 110 percent) of the measured antimony content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the antimony content of the four streams exiting the system equalled 89 to 135 percent (average 111 percent) of the antimony content of the flue gas stream entering the SNOX system.

Barium. The barium content of the two streams exiting the baghouse equalled 131 to 161 percent (average 146 percent) of the measured barium content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the barium content of the four streams exiting the system equalled 132 to 163 percent (average 146 percent) of the barium content of the flue gas stream entering the SNOX system.

Beryllium. Note that most of the reported closures on material balances are shaded indicating that non-detection played a role in the reported concentrations. The beryllium content of the two streams exiting the baghouse equalled 100 to 124 percent (average 110 percent) of the measured beryllium content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the beryllium content of the four streams exiting the system equalled 101 to 125 percent (average 111 percent) of the beryllium content of the flue gas stream entering the SNOX system.

Lead. Several samples had concentration values reported as non-detected for lead. The lead content of the two streams exiting the baghouse equalled 105 to 164 percent (average 143 percent) of the measured lead content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the lead content of the four streams exiting the system equalled 105 to 164 percent (average 143 percent) of the lead content of the flue gas stream entering the SNOX system.

Manganese. The manganese content of the two streams exiting the baghouse equalled 90 to 116 percent (average 102 percent) of the measured manganese content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the manganese content of the four streams exiting the system equalled 90 to 115 percent (average 102 percent) of the manganese content of the flue gas stream entering the SNOX system.

Nickel. The nickel content of the two streams exiting the baghouse equalled 92 to 110 percent (average 101 percent) of the measured nickel content of the flue gas stream entering the baghouse.

A calculation of the material balance for the combined system of the SO₂ reactor and WSA condenser was not made for July 22 because the reported concentration of nickel at Location 20 is believed to have been contaminated by stainless steel.

Considering the overall SNOX system, the nickel content of the four streams exiting the system equalled 92 to 110 percent (average 101 percent) of the nickel content of the flue gas stream entering the SNOX system.

The reported concentration for nickel for July 24 at Location 19 was labelled as an outlier (Table 5-4). Accordingly, the average value for July 19 and 22 was used to compute the material balance closure. The reported concentration for July 22 at Location 21 was also labelled as an outlier. Therefore the average concentration for July 19 and 24 was used to compute the material balance.

Vanadium. The vanadium content of the two streams exiting the baghouse equalled 95 to 120 percent (average 106 percent) of the measured vanadium content of the flue gas stream entering the baghouse.

High closures on the SCR reactor are reported for July 22 and 24. This may have been caused by vanadium from the catalyst material becoming entrained into the flue gas stream exiting the SCR reactor.

Considering the overall SNOX system, the vanadium content of the four streams exiting the system equalled 95 to 120 percent (average 106 percent) of the vanadium content of the flue gas stream entering the SNOX system.

Copper. The copper content of the two streams exiting the baghouse equalled 100 to 123 percent (average 112 percent) of the measured copper content of the flue gas stream entering the baghouse.

High closures are reported for copper at the SCR reactor. The reported concentrations indicate that copper was picked up across the SCR reactor.

Considering the overall SNOX system, the copper content of the four streams exiting the system equalled 100 to 123 percent (average 112 percent) of the copper content of the flue gas stream entering the SNOX system.

Cobalt. The cobalt content of the two streams exiting the baghouse equalled 80 to 110 percent (average 96 percent) of the measured cobalt content of the flue gas stream entering the baghouse.

The high closure for the SO₂ reactor and WSA condenser system on July 22 may be the result of contamination by stainless steel. Therefore this value was not used to calculate the average closure.

Considering the overall SNOX system, the cobalt content of the four streams exiting the system equalled 80 to 111 percent (average 97 percent) of the cobalt content of the flue gas stream entering the SNOX system.

6.1.3 Discussion of Material Balance Results

Tables 6-3a and 6-3b report the material balance results in two ways for ease of interpretation. In these tables for the baghouse, the elements are listed in order alphabetically (Table 6-3a) and based on the ratio of the output to the input (Table 6-3b). Tables 6-4a and 6-4b present the results for the entire SNOX system in the same fashion.

Tables 6-3a and 3b show the material balances for the baghouse. It can be seen that balances within ± 50 percent (based on average values) were achieved for 18 of the 20 elements and that balances within ± 25 percent were achieved for 13 of the elements. For one element (sodium), the quantity of the element found in the exit streams was nearly three times that reported entering the baghouse. For three of the five major elements (aluminum, potassium, and titanium), the balance for the boiler was within $+45/-0$ percent.

Tables 6-4a and 4b show the material balances for the overall SNOX system. It can be seen that balances within ± 50 percent were achieved for 17 of the 20 elements and the balance were within ± 20 percent for 12 of the elements. More than 150 percent of the incoming material was found in the exit stream for three elements. Three of the five major elements (aluminum, potassium, and titanium) produced material balances within

+50/-0 percent. Unfortunately, for one of the other major elements (sodium) the exit stream accounted for nearly 380 percent of the incoming material.

Results for the overall SNOX system tended to parallel the results for the baghouse alone. This occurs because the flue gas stream entering the baghouse and the baghouse catch represent most of the material flowing into and out of the system. Hence, these streams dominate other streams when conducting material balances.

The consistently high material balance closures for vanadium, copper, nickel, chromium, and molybdenum across the SCR reactor suggest possible erosion of these materials from the SCR catalyst. Vanadium is known to be used in the SCR catalyst. However, the sample at Location 20 for 7/19/93 may have been contaminated with stainless steel. Other elements that are frequently alloyed with stainless steel, and which gave unusually high concentrations in the Location 20 sample include molybdenum, cobalt, and copper.

6.2 Chlorine and Fluorine

Chlorine and fluorine measurements were also analyzed for closure of mass balance in spite of the compromise in sampling for anions (i.e., single point isokinetic sampling, not traverse) and analytical procedures (water soluble anion concentrations were determined, not total chloride or fluoride). This was done to check the data for consistency among the various sampling locations.

Chlorine

Figure 6-24 illustrates the results for chlorine. The chlorine in the system at the inlet to the SNOX baghouse (location 18) was predominantly in the gas phase as hydrogen chloride (HCl). Its flow rate of 19 kg/hr (41 lb/hr) was about 25 percent greater than the chlorine entering the boiler in the coal and then entering the SNOX system (about 29 percent of the flue gas flow or about 15 kg/hr). The chlorine content of the two streams exiting the baghouse equalled 86 to 141 percent (average 117 percent) of the measured chlorine content of the flue gas stream entering the baghouse.

Considering the overall SNOX system, the chlorine content of the four streams exiting the system equalled 51 to 80 percent (average 63 percent) of the chlorine content of the flue gas stream entering the SNOX system. Results are summarized below:

Material Balance Results for Chlorine (Percent)

<u>System</u>	<u>7/10/93</u>	<u>7/22/93</u>	<u>7/24/93</u>	<u>Average</u>	<u>Std. Dev.</u>
Baghouse	86	125	141	117	28
SCR Reactor	119	90	73	94	23
SO ₂ Condenser	57	71	50	59	11
SNOX System	58	80	51	63	15

These data translate into average removal efficiencies of (17), 6, 41, and 37 percent for the four systems listed above.

Fluorine

The fluorine content of the two streams exiting the baghouse equalled 82 to 127 percent (average 110 percent) of the measured fluorine content of the flue gas entering the baghouse. Considering the overall SNOX system, the fluorine content of the four streams exiting the system equalled 77 to 129 percent (average 103 percent) of the fluorine content of the flue gas stream entering the SNOX system. Although the average material balance for fluorine for all systems was within 10 percent of perfect closure, the individual closures for the three days exhibited significant scatter as shown below.

Material Balance Results for Fluorine (Percent)

<u>System</u>	<u>7/10/93</u>	<u>7/22/93</u>	<u>7/24/93</u>	<u>Average</u>	<u>Std. Dev.</u>
Baghouse	82	127	122	110	24
SCR Reactor	155	71	50	59	11
SO ₂ Condenser	80	144	69	98	41
SNOX System	102	129	77	103	26

These results translate into average removal efficiencies of (10), (6), 2.2, and 2.6 percent for the four systems listed above.

6.3 Emission Factor Determinations

Emission factors were calculated for substances leaving the SNOX system. In this section the procedures used to calculate emission factors are summarized. Then the results of the calculations are presented.

6.3.1 Emission Factor Calculations

Daily emission factors (E) were calculated as follows:

$$E, \mu\text{g}/\text{MJ} = \frac{\text{Substance loading, } \mu\text{g}/\text{Nm}^3 \times \text{Flue gas flow rate, Nm}^3/\text{min.} \times 60 \text{ min.}/\text{hr}}{\text{Firing rate, MJ}/\text{hr}}$$

where the firing rate in MJ/hr equals the firing rate in 10^6 Btu/hr times 1,055, and Nm^3 equals normal cubic meters.

$$E, \text{lb}/10^{12} \text{ Btu} = \frac{\text{Substance loading, } \mu\text{g}/\text{Nm}^3 \times \text{Flue gas flow rate, Nm}^3/\text{min.} \times 60 \text{ min.}/\text{hr}}{1,000,000 \mu\text{g}/\text{g} \times 454 \text{ g}/\text{lb} \times \text{Firing rate, } 10^{12} \text{ Btu}/\text{hr}}$$

In these equations, the term substance loading refers to the concentration of a particular substance. These equations account for the fact that only a portion of the flue gas generated in the boiler enters the SNOX system. (This is accounted for in the coal firing rate which was adjusted from full boiler conditions to the stream entering the SNOX process.)

Because Location 21 at the outlet of the SNOX system did not provide a good location at which to measure the flue gas flow rate accurately, the flue gas flow rate measured at Location 18 ahead of the baghouse was used as the basis for the flue gas flow rate in the two equations listed above. The value of the flue gas flow rate at Location 18 was corrected to account for leakage of air into the system and for the flow rate of the two support burners ahead of Location 21.

An example calculation for an emission factor is shown below. This example illustrates both the calculation procedure and the location of the data in the report. This example calculation is for mercury on July 19, 1993.

Example:

Mercury loading in stack gas = $36.2 \mu\text{g}/\text{Nm}^3$ (Table 5-8, page 5-16)

Stack gas flow rate = $2,099 \text{ Nm}^3/\text{min}$ at stack oxygen (Table 3-13b, line 10, page 3-30)

= $2,099/1.2013 \text{ Nm}^3$ at 3 percent oxygen (oxygen content was 6 percent from Table 2-2, page 2-17)

= $1,747 \text{ Nm}^3/\text{min}$

Coal feed rate Boiler No. 2 = $91,700 \text{ lb/hr}$ (Table 2-4, page 2-19)

Equivalent coal feed rate SNOX = $91,700 \times 0.281$ (Table 2-6, page 2-23)
= $25,800 \text{ lb/hr}$

Firing rate for SNOX = $25,800 \text{ lb/hr} \times 12,249 \text{ Btu/lb}$ (Table 5-52, page 5-58)
= $3.16 \times 10^8 \text{ Btu/hr}$
= $3.16 \times 10^{-4} (10^{12} \text{ Btu/hr})$.

Therefore the emission factor for mercury is

$$E = \frac{36.2 \mu\text{g}/\text{Nm}^3 \times 1,747 \text{ Nm}^3/\text{min} \times 60 \text{ min/hr}}{1 \times 10^6 \mu\text{g/g} \times 453.6 \text{ g/lb} \times 3.16 \times 10^{-4} (10^{12} \text{ Btu/hr})}$$

$$E = 26.5 \text{ lb}/10^{12} \text{ Btu.}$$

This result can be found in Table 6-5 for mercury on July 19. The same emission rate can be calculated in $\mu\text{g}/\text{MJ}$ by converting the firing rate to MJ/hr, i.e.

$$\begin{aligned} \text{Firing rate} &= 3.16 \times 10^8 \text{ Btu/hr} \times 1.055 \times 10^{-3} \text{ MJ/Btu} \\ &= 3.33 \times 10^5 \text{ MJ/hr} \end{aligned}$$

Then

$$E = \frac{36.2 \mu\text{g}/\text{Nm}^3 \times 1,747 \text{ Nm}^3/\text{min} \times 60 \text{ min/hr}}{3.33 \times 10^5 \text{ MJ/hr}}$$

$$E = 11.4 \mu\text{g}/\text{MJ.}$$

This value can be found in Table 6-6.

6.3.2 Emission Factor Results

Calculated emission factors are listed in Table 6-5 through 6-18. Shown are the daily emission factors, the average value and the estimated uncertainty (\pm 95 % confidence interval) in the average value for each emission factor. The estimated uncertainty was calculated according to procedures summarized in Appendix G.

6.3.3 Discussion of Emission Factors

The average value of the emission factors for several of the trace elements was in the range 0.2 to 1 lb/10¹² Btu. The estimated uncertainty range varies from about 20 to 300 percent of the average values and is comprised principally of uncertainty due to error in precision. The bias component of the total uncertainty generally is about a tenth of the precision error for these elements.

Manganese has a reported average emission factor of 2.6 ± 3.2 lb/10¹² Btu. The average emission factor for molybdenum is 5.4 ± 3.7 lb/10¹² Btu. The estimate of the upper limit bias accounts for about 10 percent of the reported uncertainty for manganese and about two percent for molybdenum. The precision error makes up the remainder of the estimated total uncertainty.

The average reported emission factor for mercury is 22 ± 13 lb/10¹² Btu. The estimated bias accounts for about 18 percent of the estimated total uncertainty.

Reported average emission factors for the major elements aluminum, potassium, and sodium exhibit considerable scatter and therefore estimated uncertainty. Furthermore the emission factor for silicon is known to be biased low because silicon was not analyzed in the cyclone and filter portions of the sample. Therefore it is not reported.

Average emission factors for solid phase anions range from 2 lb/10¹² Btu for phosphate to 57,000 lb/10¹² Btu for sulfate. The sulfate emission may reflect sulfuric acid mist leaving the condenser in the SNOX system. Chloride and fluoride are reported as 25

and 157 lb/10¹² Btu, respectively. The emission factors for solid phase anions in flue gas were determined from single point sampling in the duct, not traversing.

Gas phase substances ammonia, cyanide, hydrogen chloride, and hydrogen fluoride have reported average emission factors of 181, 157, 82,400, and 6,630 lb/10¹² Btu. The contribution of bias to the estimated total uncertainty for these emission factors is 4, 20, 22, and 35 percent, respectively.

The reported average emission factors for radionuclide activity generally reflect non-detected values. The emission factors range from a low of 6.38 mCi/10¹² Btu for Pb²¹² to 1,680 mCi/10¹² Btu for U²³⁴.

For volatile organic compounds, the reported average emission factors range from about 3 to 9 lb/10¹² Btu with most values reported as 3 lb/10¹² Btu based upon non-detected compounds. Emission factors for the four aldehydes range from 8 to 388 lb/10¹² Btu. Emission factors for the semivolatile organic compounds range from about 0.0007 to 0.3 lb/10¹² Btu.

6.4 Removal Efficiencies

Removal efficiencies for elements were calculated for the SNOX baghouse and for the entire SNOX system. These calculations are summarized in three parts. The procedures used to calculate removal efficiencies are followed by a presentation of the results of the calculations. Discussion of the results follows.

6.4.1 Removal Efficiency Calculations

Removal efficiencies were calculated separately for each element for on each inorganic sampling day. Calculations were made separately for the baghouse, the SCR reactor, the SO₂ reactor and WSA condenser, and for the overall SNOX system. The calculation for removal efficiency (RE) in the baghouse was:

$$\text{RE, percent} = \frac{(\text{Mass flow rate, baghouse inlet} - \text{Mass flow rate, baghouse outlet}) \times 100}{\text{Mass flow rate, baghouse inlet}}$$

where the term mass flow rate refers to the mass flow rate of a specific element in the flue gas.

The calculation for removal efficiency (RE) for the SCR reactor was:

$$\text{RE, percent} = \frac{(\text{Mass flow rate, SCR reactor inlet} - \text{Mass flow rate, SCR reactor outlet}) \times 100}{\text{Mass flow rate, SCR reactor inlet}}$$

The calculation for removal efficiency (RE) for the SO₂ reactor and condenser was:

$$\text{RE, percent} = \frac{(\text{Mass flow rate, SO}_2 \text{ reactor inlet} - \text{Mass flow rate, SO}_2 \text{-condenser outlet}) \times 100}{\text{Mass flow rate, SO}_2 \text{ reactor inlet}}$$

The calculation for removal efficiency (RE) in the overall SNOX system was:

$$\text{RE, percent} = \frac{(\text{Mass flow rate, baghouse inlet} - \text{Mass flow rate, WSA condenser outlet}) \times 100}{\text{Mass flow rate, baghouse inlet}}$$

A sample calculation of removal efficiencies for aluminum is included in the sample mass balance calculation shown in Table 6-1.

6.4.2 Removal Efficiency Results and Discussion

Table 6-19 presents calculated removal efficiencies for each of the elements. The same substitutions for outliers were made for the calculations of removal efficiencies as were made for material balances. If a removal efficiency for an element on a specific day was negative and judged to be outside of random error, it was marked with an asterisk and not used to calculate the average removal efficiency. Tables 6-20a&b and 6-21a&b present the removal efficiencies for the baghouse and for the overall SNOX system in decreasing order of removal efficiency and in alphabetical order.

Because of sampling problems discussed above, calculated removal efficiencies for the SCR reactor and for the SO₂ reactor and condenser generally were not meaningful. Hence, these results are not discussed in the following paragraphs.

Removal efficiencies in the baghouse for 16 of the 20 elements were greater than 99 percent, and removal efficiencies for 17 of the 20 elements were greater than 98 percent. Only mercury and selenium gave low removal efficiencies, although the removal efficiency for sodium was only 80 percent.

Removal efficiencies in the overall SNOX system for 16 of the 20 elements were greater than 99 percent, removal efficiencies for 18 of the 20 elements were greater than 95 percent. Only mercury gave a low removal efficiency, -13 percent.

TABLE 6-1. EXAMPLE MATERIAL BALANCE CALCULATION FOR ALUMINUM

Metals Calculations: Aluminum

Test Date	M-1 7/19/93	M-2 7/22/93	M-3 7/24/93	Average	Comments
Flue gas loadings					
SNOx Inlet (Location 18)					
1. Gas flow rate, dry, 3% O ₂	Ncm/min	1717.70	1748.00		From Table 3-13b
2. Metal loading	ug/Ncm	180855.93	179919.43		From Table 5-2
3a. Metal emissions	g/hr	18640.43	18869.95		#1*#2*60/1000000
3b. Metal emissions	lb/hr	27.38	41.60	36.69	#3a/453.6
Baghouse Outlet (Location 19)					
4. Gas flow rate, dry, 3% O ₂	Ncm/min	1716.40	1738.80		From Table 3-13b
5. Metal loading	ug/Ncm	189.85	1549.76		From Table 5-4
6a. Metal emissions	g/hr	52.65	161.68		#4*#5*60/1000000
6b. Metal emissions	lb/hr	0.12	0.36	0.17	#6a/453.6
SO ₂ Reactor Inlet (Location 20)					
7. Gas flow rate, dry, 3% O ₂	Ncm/min	1704.23	1729.16		From Table 3-13b
8. Metal loading	ug/Ncm	576.36	722.06		From Table 5-6
9a. Metal emissions	g/hr	58.94	74.91		#7*#8*60/1000000
9b. Metal emissions	lb/hr	0.13	0.17	0.15	#9a/453.6
SNOx Outlet (Location 21)					
10. Gas flow rate, dry, 3% O ₂	Ncm/min	1783.07	1794.03		From Table 3-13b
11. Metal loading	ug/Ncm	327.35	180.21		From Table 5-8 (except Run 2)
12a. Metal emissions	g/hr	35.02	19.40		#10*#11*60/1000000
12b. Metal emissions	lb/hr	0.11	0.04	0.08	#12a/453.6
Metal mass balances					
Baghouse					
13. Metal in BH inlet particulate	lb/hr	41.09	41.60	36.69	#3b
14. Metal in BH outlet particulate	lb/hr	0.12	0.36	0.17	#6b
15. Baghouse catch	lb/hr	491.03	513.84		#13-#14
16. Metal in baghouse catch	ug/g	105400.00	94900.00		From Table 5-12
17. Metal in baghouse catch	lb/hr	51.75	48.76	49.69	#15*#16/1000000
18. Total metal out	lb/hr	51.87	49.12		#14 + #17

TABLE 6-1. (Continued)

19.	Metal in - Metal out	lb/hr	-24.49	-7.50	-7.52	-13.17	#13-#18
20.	Metal out/metal in		1.89	1.18	1.18	1.42	#18/#13
SCR Reactor							
21.	Baghouse outlet metal emissions	lb/hr	0.12	0.04	0.36		#6b
22.	SCR reactor out. metal emissions	lb/hr	0.14	0.13	0.17	0.15	#9b
23.	Metal in - Metal out	lb/hr	-0.03	-0.09	0.19	0.03	#21-#22
24.	Metal out/metal in		1.23	3.01	0.46	1.57	#22/#21
SO2 Reactor & Tower							
25.	SCR outlet metal emissions	lb/hr	0.14	0.13	0.17		#9b
26.	SO2 reactor waste	lb/hr	0.00	0.00	0.00		Assumed
27.	Metal in SO2 reactor waste	ug/g	6700.00	6700.00	6700.00		From Table 5-11
28.	Metal in SO2 reactor waste	lb/hr	0.00	0.00	0.00		#26*#27/1000000
29.	Acid drain	lb/hr	2209.70	2021.40	2117.58		From SNOR system analysis
30.	Metal in acid	ug/g	15.90	12.60	12.30		From Table 5-13
31.	Metal in acid	lb/hr	0.04	0.03	0.03	0.03	#29*#30/1000000
32.	SO2 tower outlet metal emissions	lb/hr	0.11	0.08	0.04	0.08	#12b.
33.	Total metal out	lb/hr	0.14	0.10	0.07		#28+#31+#32
34.	Metal in - Metal out	lb/hr	-0.00	0.03	0.10	0.04	#25-#33
35.	Metal out/metal in		1.01	0.79	0.42	0.74	#33/#25
Total SNOR System							
36.	Metal in BH inlet particulate	lb/hr	27.38	41.09	41.60	36.69	#13
37.	Metal in baghouse catch	lb/hr	51.75	48.55	48.76	49.69	#17
38.	Metal in SO2 reactor waste	lb/hr	0.00	0.00	0.00	0.00	#28
39.	Metal in acid	lb/hr	0.04	0.03	0.03	0.03	#31
40.	SO2 tower outlet metal emissions	lb/hr	0.11	0.08	0.04	0.08	#32
41.	Total metal out	lb/hr	51.90	48.65	48.83	49.79	#37+#38+#39+#40
42.	Metal in - Metal out	lb/hr	-24.52	-7.56	-7.23	-13.10	#36-#41
43.	Metal out/metal in		1.90	1.18	1.17	1.42	#41/#36
Metal Emission Factors							
Firing Rate							
44.	Equivalent firing rate	lb/hr	25827.80	26433.43	26803.34		From Table 3-15
45.	Coal heating value	Btu/lb	12249.00	12218.00	12306.00	12257.67	From Table 5-52
46a.	Firing rate	10 ⁶ Btu/hr	316.36	322.96	329.84		#44*#45/1000000
46b.	Firing rate	MJ/hr	333764.84	340726.64	347983.15		#46a*1055

TABLE 6-1. (Continued)

Boiler emissions							
47a. Metal emissions	g/hr	12418.23	18640.43	18869.95	#3a		
47b. Metal emissions	lb/hr	27.38	41.09	41.60	#3b		
48a. Metal emission factor	ug/MJ	37206.54	54707.86	54226.62	#47a*1000000/#46b	48713.67	
48b. Metal emission factor	lb/10 ¹² Btu	86536.36	127241.61	126122.31	#47b*1000000/#46a	113300.10	
Baghouse emissions							
49a. Metal emissions	g/hr	52.65	19.55	161.68	#6a		
49b. Metal emissions	lb/hr	0.12	0.04	0.36	#6b		
50a. Metal emission factor	ug/MJ	157.75	57.38	464.63	#49a*1000000/#46b	226.59	
50b. Metal emission factor	lb/10 ¹² Btu	366.91	133.46	1080.65	#49b*1000000/#46a	527.01	
SCR Reactor emissions							
51a. Metal emissions	g/hr	64.97	58.94	74.91	#9a.		
51b. Metal emissions	lb/hr	0.14	0.13	0.17	#9b.		
52a. Metal emission factor	ug/MJ	194.67	172.97	215.28	#51a*1000000/#46b	194.31	
52b. Metal emission factor	lb/10 ¹² Btu	452.78	402.30	500.71	#51b*1000000/#46a	451.93	
SNOr emissions							
53a. Metal emissions	g/hr	49.74	35.02	19.40	#12a		
53b. Metal emissions	lb/hr	0.11	0.08	0.04	#12b		
54a. Metal emission factor	ug/MJ	149.02	102.78	55.74	#53a*1000000/#46b	102.51	
54b. Metal emission factor	lb/10 ¹² Btu	346.59	239.06	129.65	#53b*1000000/#46a	238.43	
Removal Efficiencies							
55. Baghouse	percent	99.58	99.90	99.14	(#48b-#50b)*100/#48b	99.54	
56. SCR Reactor	percent	-23.40	-201.44	53.67	(#50b-#52b)*100/#50b	-57.06	
57. SO2 Condenser	percent	23.45	40.58	74.11	(#52b-#54b)*100/#52b	46.05	
58. Total SNOr system	percent	99.60	99.81	99.90	(#48b-#54b)*100/#48b	99.77	

TABLE 6-2. MATERIAL BALANCE RESULTS FOR ELEMENTS (Percent)^(a)

Element	System	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Aluminum	Baghouse	190	118	118	142	41
Aluminum	SCR Reactor	123#	301	46	157	131
Aluminum	SO ₂ Condenser	101#	75#	42	73	30
Aluminum	SNOX System	190	118#	118	142	42
Potassium	Baghouse	135	111	142	129	16
Potassium	SCR Reactor	110#	337	26	158	161
Potassium	SO ₂ Condenser	159#	57	72	96	55
Potassium	SNOX System	135	111	141	129	16
Titanium	Baghouse	113	115	102	110	7
Titanium	SCR Reactor	112#	180	113	135	39
Titanium	SO ₂ Condenser	158#	103	87	116	37
Titanium	SNOX System	113	115	102	110	7
Silicon	Baghouse	203	167	156	175	24
Silicon	SCR Reactor	101#	99	86	95	8
Silicon	SO ₂ Condenser	0.6*#	0.7	0.6#	0.6	0
Silicon	SNOX System	201	166	154	174	24
Sodium	Baghouse	220	187#	504	303	125
Sodium	SCR Reactor	107#	71#	47	75	30
Sodium	SO ₂ Condenser	15*#	7#	46	27	NC
Sodium	SNOX System	212	157#	479	283	172

TABLE 6-2. (Continued)

Mercury	Baghouse	83	98	137	106	28
Mercury	SCR Reactor	99	111	93	101	9
Mercury	SO ₂ Condenser	137	83	120	114	28
Mercury	SNOX System	112	91	152	118	31
Selenium	Baghouse	80	126	94	100	24
Selenium	SCR Reactor	125#	111	129	122	9
Selenium	SO ₂ Condenser	274#	271	270	272	2
Selenium	SNOX System	242	343	275	287	51
Arsenic	Baghouse	63	88	89	80	15
Arsenic	SCR Reactor	8*#	20	3	10	9
Arsenic	SO ₂ Condenser	135*#	66	538*	101	NC
Arsenic	SNOX System	63	87	89	80	15
Cadmium	Baghouse	41	33	81	52	26
Cadmium	SCR Reactor	121#	208	255	195	68
Cadmium	SO ₂ Condenser	766#	617	500	627	133
Cadmium	SNOX System	47	40	99	62	32
Chromium	Baghouse	88	98	118#	101	16
Chromium	SCR Reactor	606#	271	460#	446	168
Chromium	SO ₂ Condenser	72#	94#	91	85	12
Chromium	SNOX System	88	98#	118	102	15
Molybdenum	Baghouse	52	116	141	103	46
Molybdenum	SCR Reactor	424#	426	339	396	50
Molybdenum	SO ₂ Condenser	237*#	138	126	132	NC
Molybdenum	SNOX System	57	121	145	108	45

TABLE 6-2. (Continued)

Boron	Baghouse	NA	NA	NA	NA	NA
Boron	SCR Reactor	NA	NA	NA	NA	NA
Boron	SO ₂ Condenser	NA	NA	NA	NA	NA
Boron	SNOX System	NA	NA	NA	NA	NA
Antimony	Baghouse	89	107	135	110	23
Antimony	SCR Reactor	118#	104	108	110	8
Antimony	SO ₂ Condenser	162#	175	173	170	7
Antimony	SNOX System	89	108	135	111	23
Barium	Baghouse	161	131	145	146	15
Barium	SCR Reactor	64#	370	13	149	193
Barium	SO ₂ Condenser	1,790#	896	4,810	2,500	2,040
Barium	SNOX System	163	132	146	147	16
Beryllium	Baghouse	100	107	124	110	12
Beryllium	SCR Reactor	215#	117	255	196	71
Beryllium	SO ₂ Condenser	923*#	838	500	667	NC
Beryllium	SNOX System	101	108	125	111	12
Lead	Baghouse	105	161	164	143	33
Lead	SCR Reactor	24*#	114	119	116	NC
Lead	SO ₂ Condenser	162#	175	603	313	251
Lead	SNOX System	105	161	164	143	33
Manganese	Baghouse	90	101	116	102	13
Manganese	SCR Reactor	470*#	140	261	201	NC
Manganese	SO ₂ Condenser	43#	198	26	89	95
Manganese	SNOX System	90	102	115	102	13

TABLE 6-2. (Continued)

Nickel	Baghouse	92	100	110#	101	10
Nickel	SCR Reactor	2,820*#	425	902#	664	NC
Nickel	SO ₂ Condenser	82#	166#	214	154	67
Nickel	SNOX System	92	0#	110	101	9
Vanadium	Baghouse	95	103	120	106	13
Vanadium	SCR Reactor	2,310#	1,998	2,148	2,150	155
Vanadium	SO ₂ Condenser	97#	73	117	96	22
Vanadium	SNOX System	95	103	120	106	13
Copper	Baghouse	100	112	123	112	12
Copper	SCR Reactor	1,130#	1,133	800	1,020	191
Copper	SO ₂ Condenser	12#	9	10	10	2
Copper	SNOX System	100	112	123	112	12
Cobalt	Baghouse	79	100	110	96	16
Cobalt	SCR Reactor	214#	207	250	224	23
Cobalt	SO ₂ Condenser	592#	620	500	570	63
Cobalt	SNOX System	80	100	111	97	16

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NC = Not calculated

NA = Not available

Based upon a value substituted for an outlier.

* Value not used to calculate average.

TABLE 6-3a. MATERIAL BALANCE RESULTS FOR BAGHOUSE, ALPHABETICALLY
(Percent)^(a)

Element	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Aluminum	190	118	118	142	41
Antimony	89	107	135	110	23
Arsenic	63	88	89	80	15
Barium	161	131	145	146	15
Beryllium	100	107	124	110	12
Boron	NA	NA	NA	NA	NA
Cadmium	41	33	81	52	26
Chromium	88	98	118#	101	16
Cobalt	79	100	110	96	16
Copper	100	112	123	112	12
Lead	105	161	164	143	33
Manganese	90	101	116	102	13
Mercury	83	98	137	106	28
Molybdenum	52	116	141	103	46
Nickel	92	100	110#	101	10
Potassium	135	111	142	129	16
Selenium	80	126	94	100	24
Silicon	203	167	156	175	25
Sodium	220	187#	504	303	125
Titanium	113	115	102	110	7
Vanadium	95	103	120	106	13

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

Based upon a value substituted for an outlier.

TABLE 6-3b. MATERIAL BALANCE RESULTS FOR BAGHOUSE BY
PERCENTAGE IN BALANCE (Percent)^(a)

Element	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Boron	NA	NA	NA	NA	NA
Cadmium	41	33	81	52	26
Arsenic	63	88	89	80	15
Cobalt	79	100	110	96	16
Selenium	80	126	94	100	24
Nickel	92	100	110#	101	10
Chromium	88	98	118#	101	16
Manganese	90	101	116	102	13
Molybdenum	52	116	141	103	46
Mercury	83	98	137	106	28
Vanadium	95	103	120	106	13
Titanium	113	115	102	110	7
Beryllium	100	107	124	110	12
Antimony	89	107	135	110	23
Copper	100	112	123	112	12
Potassium	135	111	142	129	16
Aluminum	190	118	118	142	41
Lead	105	161	164	143	33
Barium	161	131	145	146	15
Silicon	203	167	156	175	25
Sodium	220	187#	504	303	125

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

Based upon a value substituted for an outlier.

TABLE 6-4a. MATERIAL BALANCE RESULTS FOR THE SNOX SYSTEM,
ALPHABETICALLY (Percent)^(a)

Element	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Aluminum	190	118#	118	142	42
Antimony	89	108	135	111	23
Arsenic	63	87	89	80	15
Barium	163	132	146	147	16
Beryllium	101	108	125	111	12
Boron	NA	NA	NA	NA	NA
Cadmium	47	40	99	62	32
Chromium	88	98#	118	102	15
Cobalt	80	100	111	97	16
Copper	100	112	123	112	12
Lead	105	161	164	143	33
Manganese	90	102	115	102	13
Mercury	112	91	152	118	31
Molybdenum	57	121	145	108	45
Nickel	92	100#	110	101	9
Potassium	135	111	141	129	16
Selenium	242	343	275	287	51
Silicon	201	166	154	174	24
Sodium	212	157#	479	283	172
Titanium	113	115	102	110	7
Vanadium	95	103	120	106	13

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

Based upon a value substituted for an outlier.

TABLE 6-4b. MATERIAL BALANCE RESULTS FOR SNOX SYSTEM BY
PERCENTAGE IN BALANCE (Percent)^(a)

Element	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Boron	NA	NA	NA	NA	NA
Cadmium	47	40	99	62	32
Arsenic	63	87	89	80	15
Cobalt	80	100	111	97	16
Manganese	90	102	115	102	13
Nickel	92	100#	110	101	9
Chromium	88	98#	118	102	15
Vanadium	95	103	120	106	13
Molybdenum	57	121	145	108	45
Titanium	113	115	102	110	7
Antimony	89	108	135	111	23
Beryllium	101	108	125	111	12
Copper	100	112	123	112	12
Mercury	112	91	152	118	31
Potassium	135	111	141	129	16
Aluminum	190	118#	118	142	42
Lead	105	161	164	143	33
Barium	163	132	146	147	16
Silicon	201	166	154	174	24
Sodium	212	157#	479	283	172
Selenium	242	343	275	287	51

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

Based upon a value substituted for an outlier.

TABLE 6-5. EMISSION FACTORS FOR ELEMENTS (lb/10¹² BTU)

Analyte	N-21-MUM-719		N-21-MUM-722		N-21-MUM-724		AVERAGE	TU
Aluminum		347		#		130	240	NC
Potassium		195	ND <	0.685 *		35.3	77 ##	257
Sodium		477		#		303	390	NC
Titanium		2.64	ND <	0.0495 *		1.08	1.3 ##	3.2
Antimony	ND <	0.465	ND <	0.500	ND <	0.540	ND <	0.50
Arsenic	ND <	0.465	ND <	0.500	ND <	0.540	ND <	0.50
Barium		0.445	ND <	0.0342 *	ND <	0.0379 *	0.17 ##	0.59
Beryllium		0.275		0.181	ND <	0.0583 *	0.17 ##	0.27
Boron		NA		NA		NA	NA	NA
Cadmium		0.168	ND <	0.0503 *	ND <	0.0583 *	0.092 ##	0.16
Chromium		3.13		#		4.65	3.9	NC
Cobalt	ND <	0.201		#	ND <	0.233	ND <	0.22
Copper		1.08		1.01		0.565	0.89	0.70
Lead	ND <	0.233 *	ND <	0.250 *		1.10	0.53 ##	1.2
Manganese		1.79		4.10		2.05	2.6	3.1
Mercury		26.5		16.0		22.1	22	13
Molybdenum		5.04		7.05		4.23	5.4	3.6
Nickel		0.763		#		3.61	2.2	NC
Selenium		1.04		0.446		0.518	0.67	0.80
Vanadium	ND <	0.100	ND <	0.101	ND <	0.117	ND <	0.11

TU = Total uncertainty (95 % confidence limit).

NA = Not analyzed.

ND < = Analyte not detected.

NC = Not calculated.

* = Emission factor calculated using one half of the detection limit.

= Outlier data (see section 5), not used in calculation.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-6. EMISSION FACTORS FOR ELEMENTS ($\mu\text{g}/\text{MJ}$)

Analyte	N-21-MUM-719		N-21-MUM-722		N-21-MUM-724		AVERAGE	TU
Aluminum		149		#		55.9	100	NC
Potassium		84.0	ND <	0.295 *		15.2	33 ##	111
Sodium		205		#		130	72	NC
Titanium		1.14	ND <	0.0213 *		0.47	0.54 ##	1.4
Antimony	ND <	0.200	ND <	0.215	ND <	0.232	ND <	0.22
Arsenic	ND <	0.200	ND <	0.215	ND <	0.232	ND <	0.22
Barium		0.191	ND <	0.0147 *	ND <	0.0163 *	0.074 ##	0.25
Beryllium		0.118		0.0779	ND <	0.0251 *	0.074 ##	0.12
Boron		NA		NA		NA	NA	NA
Cadmium		0.0724	ND <	0.0217 *	ND <	0.0251 *	0.040 ##	0.070
Chromium		1.35		#		2.00	0.72	NC
Cobalt	ND <	0.0864		#	ND <	0.100	ND <	0.040
Copper		0.466		0.436		0.243	0.38	0.30
Lead	ND <	0.100 *	ND <	0.108 *		0.474	0.23 ##	0.53
Manganese		0.771		1.76		0.881	1.1	1.4
Mercury		11.4		6.89		9.51	4.0	5.6
Molybdenum		2.17		3.03		1.82	2.3	1.6
Nickel		0.328		#		1.55	0.40	NC
Selenium		0.446		0.192		0.223	0.29	0.35
Vanadium	ND <	0.0432	ND <	0.0433	ND <	0.0502	ND <	0.046

TU = Total uncertainty (95 % confidence limit).

NA = Not analyzed.

ND < = Analyte not detected.

NC = Not calculated.

* = Emission factor calculated using one half of the detection limit.

= Outlier data (see section 5), not used in calculation.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-7. EMISSION FACTORS FOR AMMONIA/CYANIDE (lb/10¹² BTU)

Analyte	N-21-NH4-719	N-21-NH4-722	N-21-NH4-724	AVERAGE	TU
	N-21-CN-719	N-21-CN-722	N-21-CN-724		
Ammonia	49.1	#	62.2	56	NC
Cyanide	133	145	194	157	82

TU = Total uncertainty (95 % confidence limit).

NC = Not calculated.

= Outlier data (see section 5), not used in calculation.

TABLE 6-8. EMISSION FACTORS FOR AMMONIA/CYANIDE (μg/MJ)

Analyte	N-21-NH4-719	N-21-NH4-722	N-21-NH4-724	AVERAGE	TU
	N-21-CN-719	N-21-CN-722	N-21-CN-724		
Ammonia	21.1	#	26.8	10	NC
Cyanide	57.1	62.3	83.3	68	35

TU = Total uncertainty (95 % confidence limit).

NC = Not calculated.

= Outlier data (see section 5), not used in calculation.

TABLE 6-9. EMISSION FACTORS FOR ANIONS (lb/10¹² BTU)

Analyte	N-21-FCL-719	N-21-FCL-722	N-21-FCL-724	AVERAGE	TU
Hydrogen Chloride	79800	100000	67400	82400	41800
Hydrogen Fluoride	6730	7370	5780	6630	2110
Chloride (Particulate) **	4.82	ND < 6.10 *	62.7	25 ##	82
Fluoride (Particulate) **	446	4.24	20.6	157	621
Phosphate (Particulate) **	3.46	ND < 0.610 *	ND < 1.99 *	2.0 ##	3.5
Sulfate (Particulate) **	45400	39500	85000	56600	61700

TU = Total uncertainty (95 % confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

** = Sampling for anions was conducted at a single point in the duct; traverses were not made.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-10. EMISSION FACTORS FOR ANIONS (μg/MJ)

Analyte	N-21-FCL-719	N-21-FCL-722	N-21-FCL-724	AVERAGE	TU
Hydrogen Chloride	34300	43000	29000	35500	18000
Hydrogen Fluoride	2900	3170	2490	2850	910
Chloride	2.08	ND < 2.62	27.0	11	35
Fluoride	192	1.83	8.85	68	267
Phosphate	1.49	ND < 0.262	ND < 0.855	0.87	1.5
Sulfate	19500	17000	36600	24400	26600

TU = Total uncertainty (95 % confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

** = Sampling for anions was conducted at a single point in the duct; traverses were not made.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-11. EMISSION FACTORS FOR VOC (lb/10¹² BTU)

Analyte	N-21-VOC-718		N-21-VOC-721		N-21-VOC-723		AVERAGE	TU
Chloromethane		433		149		72.4	218	472
Bromomethane	ND <	5.70 *		13.1		9.92	9.6 ##	9.3
Vinyl Chloride	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Chloroethane	ND <	2.65 *	ND <	3.70 *		3.94	3.4 ##	1.8
Methylene Chloride		NC		NC		NC	NC	NC
Acetone		NC		NC		NC	NC	NC
Carbon Disulfide	ND <	5.70 *	ND <	7.31 *		3.30	5.4 ##	5.0
1,1-Dichloroethene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
1,1-Dichloroethane	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
trans-1,2-Dichloroethene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Chloroform	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
1,2-Dichloroethane	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
2-Butanone	ND <	5.29	ND <	14.6	ND <	4.86	ND <	8.3
1,1,1-Trichloroethane	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Carbon Tetrachloride	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Vinyl Acetate	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Bromodichloromethane	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
1,2-Dichloropropane	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
cis-1,3-Dichloropropylene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Trichloroethene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Dibromochloromethane	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
1,1,2-Trichloroethane	ND <	2.65 *		9.64	ND <	2.43 *	4.9 ##	10
Benzene		3.63		5.96		7.16	5.6	4.5
trans-1,3-Dichloropropylene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
2-Chloroethylvinylether	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Bromoform	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
4-Methyl-2-Pentanone	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
2-Hexanone		11.8		41.6	ND <	2.43 *	19 ##	51
Tetrachloroethene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
1,1,2,2-Tetrachloroethane	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Toluene		6.39	ND <	2.91 *		2.52	3.9 ##	5.3
Chlorobenzene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Ethylbenzene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Styrene	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8
Xylenes (Total)	ND <	5.29	ND <	7.39	ND <	4.86	ND <	5.8

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

NC = Not calculated.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-12. EMISSION FACTORS FOR VOC (µg/MJ)

Analyte	N-21-VOC-718		N-21-VOC-721		N-21-VOC-723		AVERAGE	TU
Chloromethane		186		64.0		31.2	94	203
Bromomethane	ND <	2.45 *		5.63		4.27	4.1 ##	4.0
Vinyl Chloride	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Chloroethane	ND <	1.14 *	ND <	1.59 *		1.70	1.5 ##	0.8
Methylene Chloride		NC		NC		NC	NC	NC
Acetone		NC		NC		NC	NC	NC
Carbon Disulfide	ND <	2.45 *	ND <	3.14 *		1.42	2.3 ##	2.2
1,1-Dichloroethene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
1,1-Dichloroethane	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
trans-1,2-Dichloroethene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Chloroform	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
1,2-Dichloroethane	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
2-Butanone	ND <	2.28	ND <	6.29	ND <	2.09	ND <	3.6
1,1,1-Trichloroethane	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Carbon Tetrachloride	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Vinyl Acetate	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Bromodichloromethane	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
1,2-Dichloropropane	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
cis-1,3-Dichloropropylene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Trichloroethene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Dibromochloromethane	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
1,1,2-Trichloroethane	ND <	1.14 *		4.15	ND <	1.05 *	2.1 ##	4.4
Benzene		1.56		2.57		3.08	2.4	1.9
trans-1,3-Dichloropropylene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
2-Chloroethylvinylether	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Bromoform	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
4-Methyl-2-Pentanone	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
2-Hexanone		5.08		17.9	ND <	1.05 *	8.0 ##	22
Tetrachloroethene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
1,1,2,2-Tetrachloroethane	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Toluene		2.75	ND <	1.25 *		1.09	1.7 ##	2.3
Chlorobenzene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Ethylbenzene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Styrene	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5
Xylenes (Total)	ND <	2.28	ND <	3.18	ND <	2.09	ND <	2.5

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

NC = Not calculated.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-13. EMISSION FACTORS FOR PAH/SVOC (lb/10¹² BTU)

Analyte	N-21-MM-F+X-718		N-21-MM-F+X-721		N-21-MM-F+X-723		AVERAGE	TU
Benzylchloride		0.00178		0.0703	ND <	0.00362 *	0.025 ##	0.097
Acetophenone		0.106		0.343		0.456	0.30	0.44
Hexachloroethane	ND <	0.000757	ND <	0.00838	ND <	0.00724	ND <	0.0055
Naphthalene		0.0624		0.0822		0.0344	0.060	0.060
Hexachlorobutadiene	ND <	0.000757	ND <	0.00838	ND <	0.00724	ND <	0.0055
2-Chloroacetophenone	ND <	0.000757	ND <	0.00838	ND <	0.00724	ND <	0.0055
2-Methylnaphthalene		0.0105		0.0402		0.00894	0.020	0.044
1-Methylnaphthalene		0.00595		0.0222		0.00604	0.011	0.023
Hexachlorocyclopentadiene	ND <	0.000757	ND <	0.00838	ND <	0.00724	ND <	0.0055
Biphenyl		0.0143		0.00286	ND <	0.000724 *	0.0060 ##	0.018
Acenaphthylene		0.00212		0.00772		0.00264	0.0042	0.0077
2,6-Dinitrotoluene	ND <	0.000757	ND <	0.00838	ND <	0.00724	ND <	0.0055
Acenaphthene		0.00555		0.00838		0.00212	0.0053	0.0078
Dibenzofuran		0.0127		0.0174		0.00998	0.013	0.0095
2,4-Dinitrotoluene		0.00364	ND <	0.00419 *	ND <	0.00362 *	0.0038 ##	0.00091
Fluorene		0.000243	ND <	0.000838 *	ND <	0.000724 *	0.00060 ##	0.00079
Hexachlorobenzene	ND <	0.000757	ND <	0.00838	ND <	0.00724	ND <	0.0055
Pentachlorophenol		0.00178	ND <	0.00419 *	ND <	0.00362 *	0.0032 ##	0.0031
Phenanthrene		0.0368		0.0201		0.0157	0.024	0.028
Anthracene		0.00154		0.00560		0.00359	0.0036	0.0050
Fluoranthene		0.00986		0.00619		0.00456	0.0069	0.0068
Pyrene		0.000444		0.00247	ND <	0.000724 *	0.0012 ##	0.0027
Benz(a)anthracene		0.00202		0.00202		0.00239	0.0021	0.00058
Chrysene		0.00317	ND <	0.000838 *		0.00240	0.0021 ##	0.0030
Benzo(b & k)fluoranthene		0.00482		0.00316		0.00373	0.0039	0.0021
Benzo(e)pyrene		0.00182	ND <	0.000838 *	ND <	0.000724 *	0.0011 ##	0.0015
Benzo(a)pyrene		0.00126	ND <	0.000838 *	ND <	0.000724 *	0.00094 ##	0.00071
Indeno(1,2,3-c,d)pyrene		0.00149	ND <	0.000838 *	ND <	0.000724 *	0.0010 ##	0.0010
Dibenz(a,h)anthracene		0.000558	ND <	0.000838 *	ND <	0.000724 *	0.00071 ##	0.00036
Benzo(g,h,i)perylene		0.00124	ND <	0.000838 *	ND <	0.000724 *	0.00093 ##	0.00068

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-14. EMISSION FACTORS FOR PAH/SVOC (µg/MJ)

Analyte	N-21-MM-F+X-718	N-21-MM-F+X-721	N-21-MM-F+X-723	AVERAGE	TU
Benzylchloride	0.000765	0.0303	ND <	0.00156 *	0.011 ## 0.042
Acetophenone	0.0458	0.148		0.196	0.13 0.19
Hexachloroethane	ND < 0.000326	ND < 0.00361	ND < 0.00311	ND < 0.0023	0.0023 0.0023
Naphthalene	0.0268	0.0354	0.0148	0.026	0.026 0.026
Hexachlorobutadiene	ND < 0.000326	ND < 0.00361	ND < 0.00311	ND < 0.0023	0.0023 0.0023
2-Chloroacetophenone	ND < 0.000326	ND < 0.00361	ND < 0.00311	ND < 0.0023	0.0023 0.0023
2-Methylnaphthalene	0.00452	0.0173	0.00385	0.0086	0.019 0.019
1-Methylnaphthalene	0.00256	0.00957	0.00260	0.0049	0.010 0.010
Hexachlorocyclopentadiene	ND < 0.000326	ND < 0.00361	ND < 0.00311	ND < 0.0023	0.0023 0.0023
Biphenyl	0.00616	0.00123	ND < 0.000311 *	0.0026 ##	0.0078 0.0078
Acenaphthylene	0.000911	0.00332	0.00113	0.0018	0.0033 0.0033
2,6-Dinitrotoluene	ND < 0.000326	ND < 0.00361	ND < 0.00311	ND < 0.0023	0.0023 0.0023
Acenaphthene	0.00239	0.00361	0.000912	0.0023	0.0034 0.0034
Dibenzofuran	0.00547	0.00750	0.00429	0.0058	0.0041 0.0041
2,4-Dinitrotoluene	0.00157	ND < 0.00180 *	ND < 0.00156 *	0.0016 ##	0.00039 0.00039
Fluorene	0.000105	ND < 0.000361 *	ND < 0.000311 *	0.00026 ##	0.00034 0.00034
Hexachlorobenzene	ND < 0.000326	ND < 0.00361	ND < 0.00311	ND < 0.0023	0.0023 0.0023
Pentachlorophenol	0.000766	ND < 0.00180 *	ND < 0.00156 *	0.0014 ##	0.0014 0.0014
Phenanthrene	0.0158	0.00865	0.00677	0.010	0.012 0.012
Anthracene	0.000664	0.00241	0.00154	0.0015	0.0022 0.0022
Fluoranthene	0.00424	0.00266	0.00196	0.0030	0.0029 0.0029
Pyrene	0.000191	0.00106	ND < 0.000311 *	0.00052 ##	0.0012 0.0012
Benz(a)anthracene	0.000871	0.000867	0.00103	0.00092	0.00025 0.00025
Chrysene	0.00136	ND < 0.000361 *	0.00103	0.00092 ##	0.0013 0.0013
Benzo(b & k)fluoranthene	0.00208	0.00136	0.00161	0.0017	0.0009 0.0009
Benzo(e)pyrene	0.000783	ND < 0.000361 *	ND < 0.000311 *	0.00049 ##	0.00064 0.00064
Benzo(a)pyrene	0.000544	ND < 0.000361 *	ND < 0.000311 *	0.00041 ##	0.00031 0.00031
Indeno(1,2,3-c,d)pyrene	0.000641	ND < 0.000361 *	ND < 0.000311 *	0.00044 ##	0.00044 0.00044
Dibenz(a,h)anthracene	0.000240	ND < 0.000361 *	ND < 0.000311 *	0.00030 ##	0.00015 0.00015
Benzo(g,h,i)perylene	0.000534	ND < 0.000361 *	ND < 0.000311 *	0.00040 ##	0.00029 0.00029

TU = Total uncertainty (95% confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-15. EMISSION FACTORS FOR ALDEHYDES (lb/10¹² BTU)

Analyte	N-21-ALD-718	N-21-ALD-721	N-21-ALD-723	AVERAGE	TU
Formaldehyde	46.2	61.1	63.3	57	24
Acetaldehyde	356	444	366	388	127
Acrolein	7.66	7.44	9.83	8.3	3.4
Propionaldehyde	22.5	9.81	6.82	13	21

TU = Total uncertainty (95 % confidence limit).

TABLE 6-16. EMISSION FACTORS FOR ALDEHYDES (μg/MJ)

Analyte	N-21-ALD-718	N-21-ALD-721	N-21-ALD-723	AVERAGE	TU
Formaldehyde	19.9	26.3	27.3	24	10
Acetaldehyde	153	191	157	167	54
Acrolein	3.29	3.20	4.23	3.6	1.5
Propionaldehyde	9.69	4.22	2.93	5.6	8.9

TU = Total uncertainty (95 % confidence limit).

TABLE 6-17. EMISSION FACTORS FOR RADIONUCLIDES (lb/10¹² BTU)

Analyte	N-21-NH ₄ CN-719		N-21-NH ₄ CN-722		N-21-NH ₄ CN-724		AVERAGE	TU
Pb-212	ND <	5.35	ND <	6.66	ND <	12.8	ND < 8.3	8.3
Th-234		61.8	ND <	27.7 *	ND <	50.4 *	47 ##	43
Pb-210	ND <	66.2	ND <	55.5	ND <	161	ND < 94	94
Pb-211	ND <	99.3	ND <	88.8	ND <	168	ND < 119	119
Ra-226	ND <	9.38	ND <	9.43	ND <	16.1	ND < 12	12
Ra-228	ND <	23.7	ND <	20.5	ND <	36.3	ND < 27	27
Th-229	ND <	42.5	ND <	42.2	ND <	65.8	ND < 50	50
Th-230	ND <	403	ND <	411	ND <	806	ND < 540	540
U-234	ND <	1430	ND <	1610	ND <	3360	ND < 2130	2130
U-235	ND <	16.0	ND <	178	ND <	32.9	ND < 75	75

TU = Total uncertainty (95 % confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-18. EMISSION FACTORS FOR RADIONUCLIDES (μg/MJ)

Analyte	N-21-NH ₄ CN-719		N-21-NH ₄ CN-722		N-21-NH ₄ CN-724		AVERAGE	TU
Pb-212	ND <	5.07	ND <	6.31	ND <	12.1	ND < 7.8	7.8
Th-234		58.6	ND <	26.3 *	ND <	47.7 *	44 ##	41
Pb-210	ND <	62.8	ND <	52.6	ND <	153	ND < 89	89
Pb-211	ND <	94.2	ND <	84.2	ND <	159	ND < 112	112
Ra-226	ND <	8.89	ND <	8.94	ND <	15.3	ND < 11	11
Ra-228	ND <	22.5	ND <	19.5	ND <	34.4	ND < 25	25
Th-229	ND <	40.3	ND <	40.0	ND <	62.4	ND < 48	48
Th-230	ND <	382	ND <	389	ND <	764	ND < 512	512
U-234	ND <	1360	ND <	1530	ND <	3180	ND < 2020	2020
U-235	ND <	15.2	ND <	168	ND <	31.2	ND < 72	72

TU = Total uncertainty (95 % confidence limit).

ND < = Analyte not detected.

* = Emission factor calculated using one half of the detection limit.

= Average emission factor includes one or two non-detects out of three measurements.

TABLE 6-19. REMOVAL EFFICIENCY BY PERCENTAGE REMOVAL (Percent)^(a)

Element	System	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Aluminum	Baghouse	99.58	99.90	99.14	99.54	0
Aluminum	SCR Reactor	(23)*#	(201)*	54	NC	NC
Aluminum	SO ₂ Condenser	23#	43	74	47	26
Aluminum	SNOX System	99.60	99.82#	99.90	99.77	0
Potassium	Baghouse	99.35	99.80	97.91	99.02	1
Potassium	SCR Reactor	(10)*#	(237)*	74	NC	NC
Potassium	SO ₂ Condenser	4*#	99.70	80.23	89.97	NC
Potassium	SNOX System	99.31	100	99.89	99.73	0
Titanium	Baghouse	99.96	99.98	99.96	99.97	0
Titanium	SCR Reactor	(12)*#	(80)*	(13)*	NC	NC
Titanium	SO ₂ Condenser	41*#	98.68	78.91	88.80	NC
Titanium	SNOX System	99.97	100	99.99	99.99	0
Silicon	Baghouse	98.39	98.52	98.45	98.45	0
Silicon	SCR Reactor	(1)*#	1*	99.81#	NC	NC
Silicon	SO ₂ Condenser	99.58#	99.49	99.78#	99.52	0
Silicon	SNOX System	99.99	99.99	99.99	99.99	0
Sodium	Baghouse	75.37	97.48#	67.41	80.09	16
Sodium	SCR Reactor	(7)*#	29*#	53.04	NC	NC
Sodium	SO ₂ Condenser	39*#	54#	59.38	56	NC
Sodium	SNOX System	83.85	99.47#	93.78	92.37	8
Mercury	Baghouse	18	3	(36)	(5)	28
Mercury	SCR Reactor	1	(11)	7	(1)	9
Mercury	SO ₂ Condenser	(34)	21	(15)	(10)	28
Mercury	SNOX System	(8)	15	(45)	(13)	30

TABLE 6-19. (Continued)

Element	System	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Selenium	Baghouse	32.92	(7.52)	26.92	17.44	22
Selenium	SCR Reactor	(25)#	(11)	(29)	(22)	9
Selenium	SO ₂ Condenser	98.56#	99.42	99.23	99.07	0
Selenium	SNOX System	98.79	99.31	99.27	99.12	0
Arsenic	Baghouse	99.56	99.58	99.69	99.61	0
Arsenic	SCR Reactor	92.34#	79.92	96.99	89.75	9
Arsenic	SO ₂ Condenser	75.44#	85.33	(40)*	80.39	NC
Arsenic	SNOX System	99.99	99.99	99.99	99.99	0
Cadmium	Baghouse	99.28	99.36	98.48	99.04	1
Cadmium	SCR Reactor	(21)*#	(108)*	(155)*	NC	NC
Cadmium	SO ₂ Condenser	(149)*#	15	23	19	NC
Cadmium	SNOX System	97.83	98.86	97.01	97.90	1
Chromium	Baghouse	99.83	99.62	98.50#	99.32	1
Chromium	SCR Reactor	(506)*#	(171)*	(360)*#	NC	NC
Chromium	SO ₂ Condenser	35*#	73#	15	NC	NC
Chromium	SNOX System	99.32	99.12#	98.84	99.09	0
Molybdenum	Baghouse	99.39	98.93	98.80	99.04	0
Molybdenum	SCR Reactor	(324)*#	(326)*	(239)*	NC	NC
Molybdenum	SO ₂ Condenser	24#	4*	29	27	NC
Molybdenum	SNOX System	98.05	95.62	97.09	96.92	1
Boron	Baghouse	NA	NA	NA	NA	NA
Boron	SCR Reactor	NA	NA	NA	NA	NA
Boron	SO ₂ Condenser	NA	NA	NA	NA	NA
Boron	SNOX System	NA	NA	NA	NA	NA

TABLE 6-19. (Continued)

Element	System	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Antimony	Baghouse	99.79	99.70	99.72	99.74	0
Antimony	SCR Reactor	(18)#	(4)	(8)	(10)	7
Antimony	SO ₂ Condenser	25#	(40)*	(40)*	NC	NC
Antimony	SNOX System	99.69	99.57	99.58	99.61	0
Barium	Baghouse	99.83	99.96	99.83	99.87	0
Barium	SCR Reactor	36#	(270)*	87	NC	NC
Barium	SO ₂ Condenser	44*#	97.47	83.70	90.59	NC
Barium	SNOX System	99.94	100	100	99.98	0
Beryllium	Baghouse	99.95	99.90	99.94	99.93	0
Beryllium	SCR Reactor	(114)*#	(17)*	(155)*	NC	NC
Beryllium	SO ₂ Condenser	(306)*#	(207)*	23	NC	NC
Beryllium	SNOX System	99.54	99.65	99.89	99.69	0
Lead	Baghouse	99.90	99.97	99.97	99.95	0
Lead	SCR Reactor	76#	(14)*	(19)*	NC	NC
Lead	SO ₂ Condenser	25#	(40)*	(470)*	NC	NC
Lead	SNOX System	99.97	99.95	99.81	99.91	0
Manganese	Baghouse	99.74	99.57	99.05	99.45	0
Manganese	SCR Reactor	(370)*	(40)*	(161)*	NC	NC
Manganese	SO ₂ Condenser	69	(72)*	78	73	NC
Manganese	SNOX System	99.62	98.96	99.44	99.34	0
Nickel	Baghouse	99.99	99.92	99.96#	99.95	1
Nickel	SCR Reactor	(2,720)*#	(325)*	(802)*#	NC	NC
Nickel	SO ₂ Condenser	57#	(20)*#	(82)*	NC	NC
Nickel	SNOX System	99.83	99.57#	99.28	99.56	0

TABLE 6-19. (Continued)

Element	System	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Vanadium	Baghouse	100	100	100	100	0
Vanadium	SCR Reactor	(2,210)*#	(1,898)*	(2,048)*	NC	NC
Vanadium	SO ₂ Condenser	87.84#	89.82	82.01	86.56	4
Vanadium	SNOX System	99.99	99.99	99.99	99.99	0
Copper	Baghouse	99.84	99.78	99.81	99.81	0
Copper	SCR Reactor	(1,030)*#	(1,033)*	(700)*	NC	NC
Copper	SO ₂ Condenser	90.87#	93.26	93.55	92.56	1
Copper	SNOX System	99.83	99.83	99.90	99.86	0
Cobalt	Baghouse	99.95	99.96	99.96	99.96	0
Cobalt	SCR Reactor	(114)*#	(107)*	12.85	NC	NC
Cobalt	SO ₂ Condenser	26	14	23	21	6
Cobalt	SNOX System	99.93	99.93	99.92	99.93	0

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

NC = Not calculated

* = Value not used to calculate average.

Based upon a value substituted for an outlier.

TABLE 6-20a. REMOVAL EFFICIENCY FOR BAGHOUSE, ALPHABETICALLY (Percent)^(a)

Element	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Aluminum	99.58	99.90	99.14	99.54	0
Antimony	99.79	99.70	99.72	99.74	0
Arsenic	99.56	99.58	99.69	99.61	0
Barium	99.83	99.96	99.83	99.87	0
Beryllium	99.95	99.90	99.94	99.93	0
Boron	NA	NA	NA	NA	NA
Cadmium	99.28	99.36	98.48	99.04	1
Chromium	99.83	99.62	98.50#	99.32	1
Cobalt	99.95	99.96	99.96	99.96	0
Copper	99.84	99.78	99.81	99.81	0
Lead	99.90	99.97	99.97	99.95	0
Manganese	99.74	99.57	99.05	99.45	0
Mercury	18	3	(36)	(5)	28
Molybdenum	99.39	98.93	98.80	99.04	0
Nickel	99.99	99.92	99.96#	99.95	1
Potassium	99.35	99.80	97.91	99.02	1
Selenium	32.92	(7.52)	26.92	17.44	22
Silicon	98.39	98.52	98.45	98.45	0
Sodium	75.37	97.48#	67.41	80.09	16
Titanium	99.96	99.98	99.96	99.97	0
Vanadium	100	100	100	100	0

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

Based upon a value substituted for an outlier.

TABLE 6-20b. REMOVAL EFFICIENCY FOR BAGHOUSE BY PERCENTAGE (Percent)^(a)

Element	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Boron	NA	NA	NA	NA	NA
Mercury	18	3	(36)	(5)	28
Selenium	32.92	(7.52)	26.92	17.44	22
Sodium	75.37	97.48#	67.41	80.09	16
Silicon	98.39	98.52	98.45	98.45	0
Potassium	99.35	99.80	97.91	99.02	1
Molybdenum	99.39	98.93	98.80	99.04	0
Cadmium	99.28	99.36	98.48	99.04	0
Chromium	99.83	99.62	98.50#	99.32	1
Manganese	99.74	99.57	99.05	99.45	0
Aluminum	99.58	99.90	99.14	99.54	0
Arsenic	99.56	99.58	99.69	99.61	0
Antimony	99.79	99.70	99.72	99.74	0
Copper	99.84	99.78	99.81	99.81	0
Barium	99.83	99.96	99.83	99.87	0
Beryllium	99.95	99.90	99.94	99.93	0
Lead	99.90	99.97	99.97	99.95	0
Nickel	99.99	99.92	99.96#	99.95	1
Cobalt	99.95	99.96	99.96	99.96	0
Titanium	99.96	99.98	99.96	99.97	0
Vanadium	100	100	100	100	0

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

Based upon a value substituted for an outlier.

TABLE 6-21a. REMOVAL EFFICIENCY FOR SNOX SYSTEM, ALPHABETICALLY (Percent)^(a)

Element	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Aluminum	99.60	99.82	99.90	99.77	0
Antimony	99.69	99.57	99.58	99.61	0
Arsenic	99.99	99.99	99.99	99.99	0
Barium	99.94	100	100	99.98	0
Beryllium	99.54	99.65	99.89	99.69	0
Boron	NA	NA	NA	NA	NA
Cadmium	97.83	98.86	97.01	97.90	1
Chromium	99.32	99.12#	98.84	99.09	0
Cobalt	99.93	99.93	99.92	99.93	0
Copper	99.83	99.83	99.90	99.86	0
Lead	99.97	99.95	99.81	99.91	0
Manganese	99.62	98.62	99.44	99.34	0
Mercury	(8)	15	(45)	(13)	30
Molybdenum	98.05	95.62	97.09	96.92	1
Nickel	99.83	99.57#	99.28	99.56	0
Potassium	99.31	100	99.89	99.73	0
Selenium	98.79	99.31	99.27	99.12	0
Silicon	99.99	99.99	99.99	99.99	0
Sodium	83.85	89.81	93.78	89.15	5
Titanium	99.97	100	99.99	99.99	0
Vanadium	99.99	99.99	99.99	99.99	0

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

Based upon value substituted for an outlier.

TABLE 6-21b. REMOVAL EFFICIENCY FOR SNOX SYSTEM BY PERCENTAGE (Percent)^(a)

Element	7/19/93	7/22/93	7/24/93	Average	Standard Deviation
Boron	NA	NA	NA	NA	NA
Mercury	(8)	15	(45)	(13)	30
Sodium	83.85	99.47	93.78	92.37	8
Molybdenum	98.05	95.62	97.09	96.92	1
Cadmium	97.83	98.86	97.01	97.90	1
Chromium	99.32	99.12#	98.84	99.09	0
Selenium	98.79	99.31	99.27	99.12	0
Manganese	99.62	98.62	99.44	99.34	0
Nickel	99.83	99.57#	99.28	99.56	0
Antimony	99.69	99.57	99.58	99.61	0
Beryllium	99.54	99.65	99.89	99.69	0
Potassium	99.31	100	99.89	99.73	0
Aluminum	99.60	99.82	99.90	99.77	0
Copper	99.83	99.83	99.90	99.86	0
Lead	99.97	99.95	99.81	99.91	0
Cobalt	99.93	99.93	99.92	99.93	0
Barium	99.94	100	100	99.98	0
Titanium	99.97	100	99.99	99.99	0
Arsenic	99.99	99.99	99.99	99.99	0
Vanadium	99.99	99.99	99.99	99.99	0
Silicon	99.99	99.99	99.99	99.99	0

(a) Shaded values indicate at least one non-detect value was used in calculating the result.

Based upon a value substituted for an outlier.

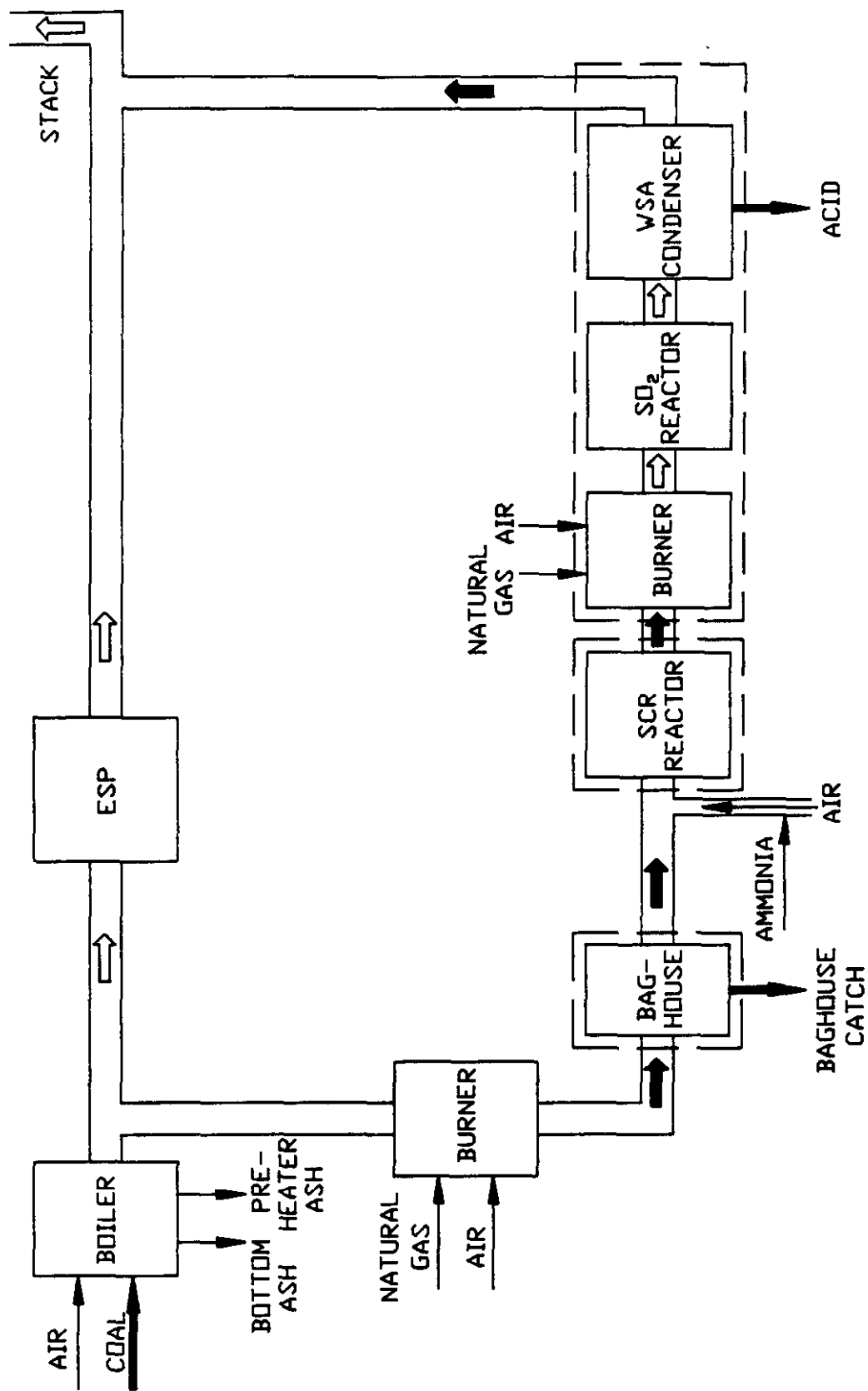


Figure 6-1. Boundaries for material balances on baghouse, SCR reactor, and SO_2 reactor and WSA condenser

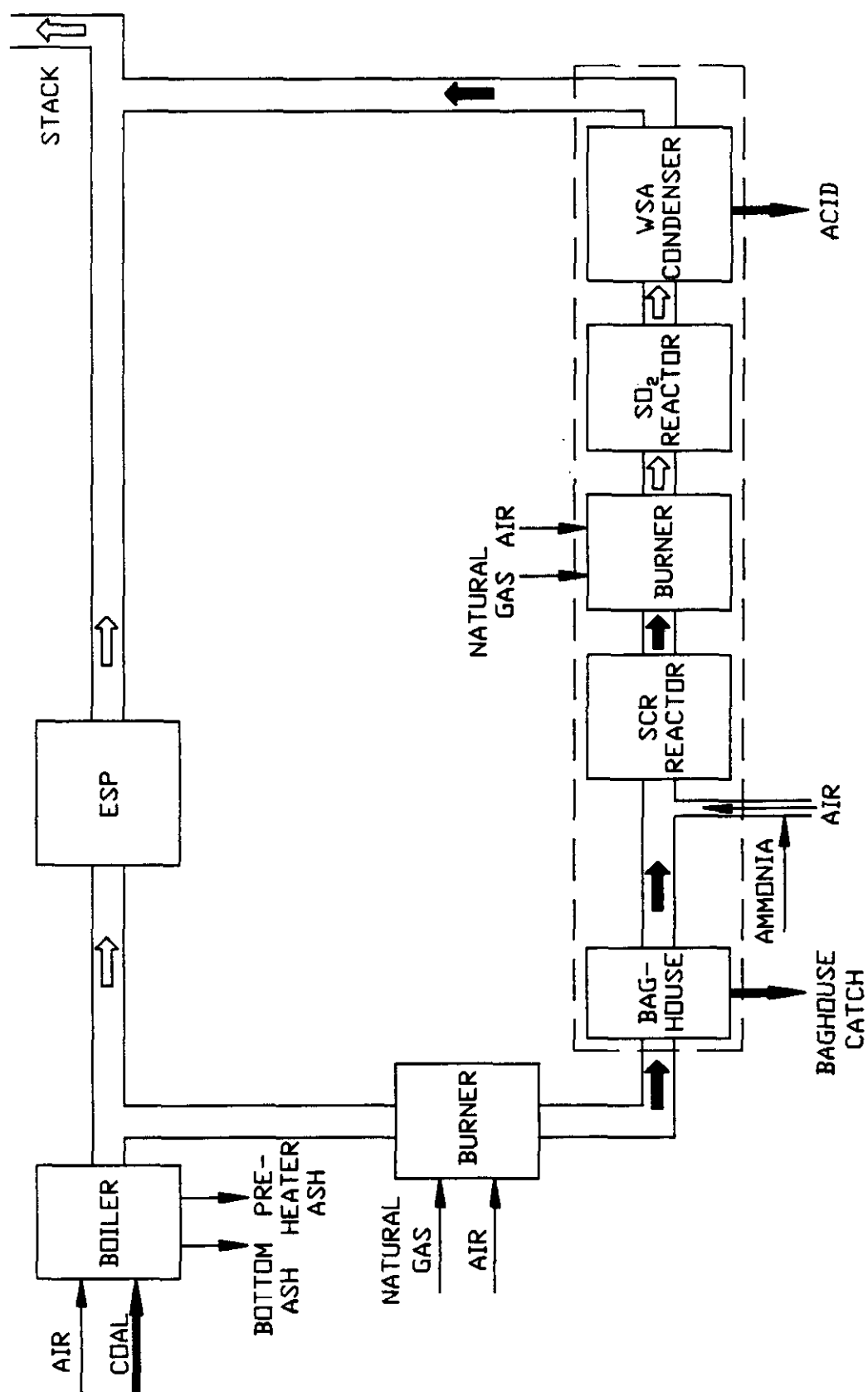


Figure 6-2. Boundary for material balance on entire SNOX system

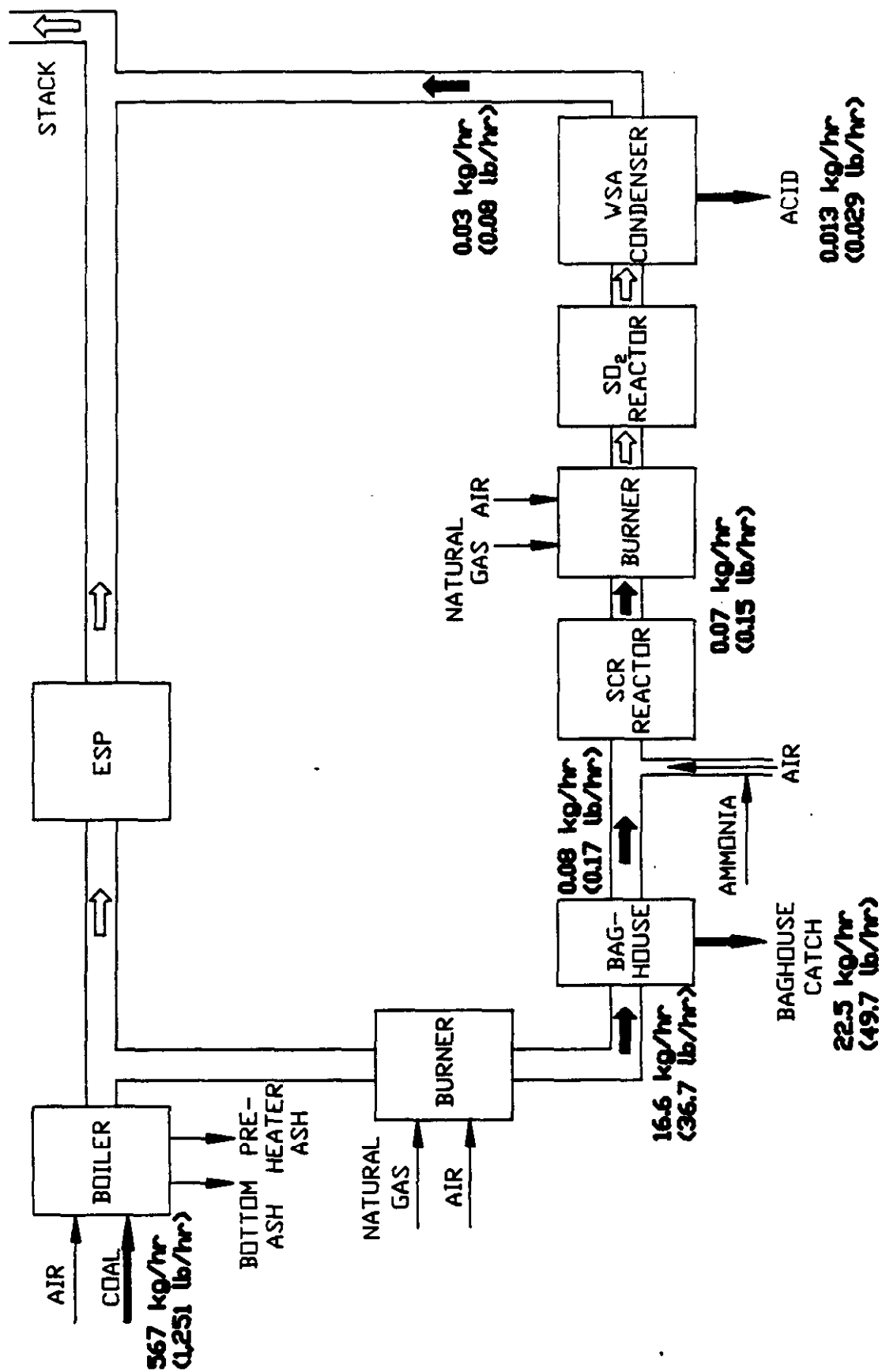


Figure 6-3. Aluminum balance for SNOX system

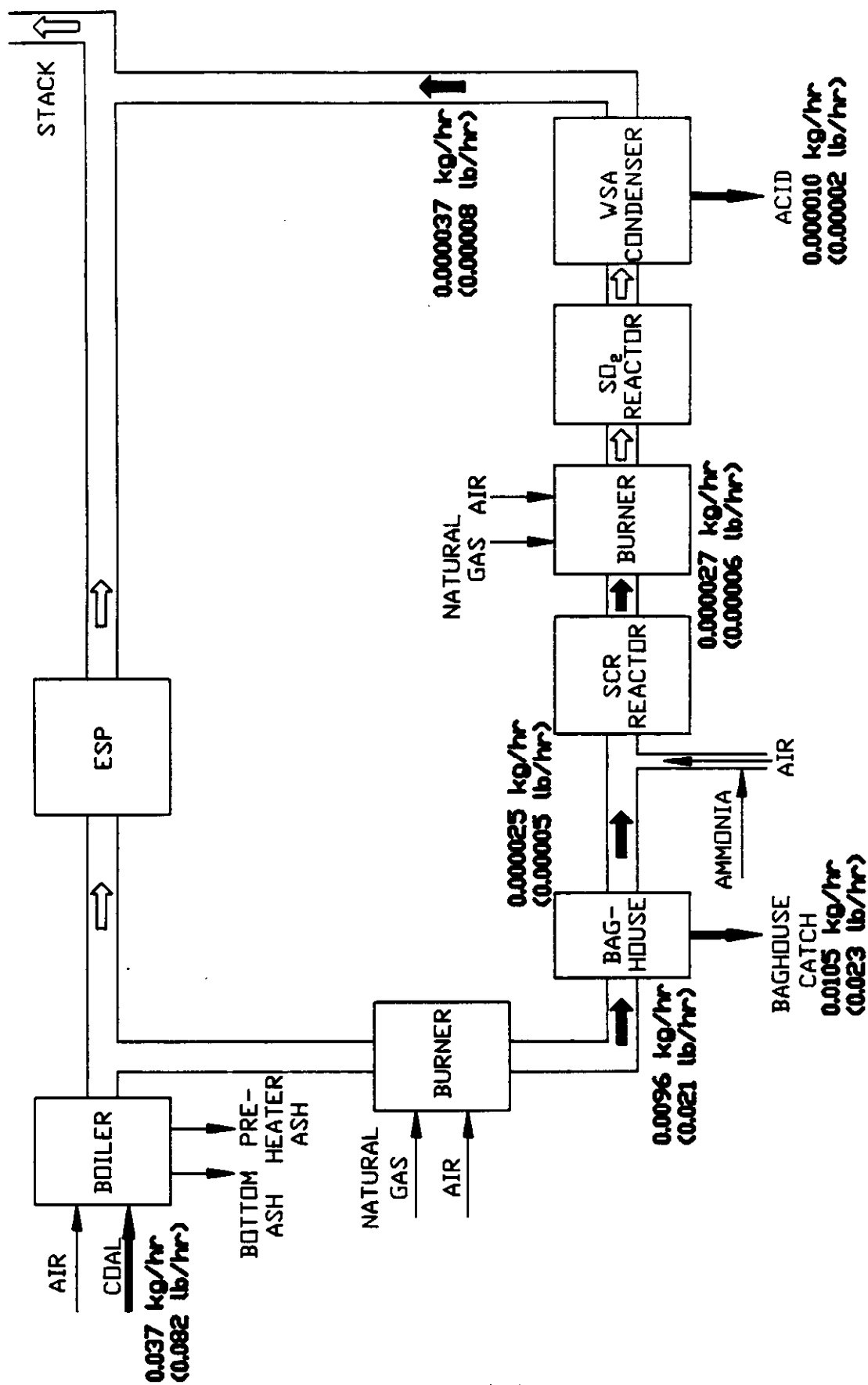


Figure 6-4. Antimony balance for SNOX system

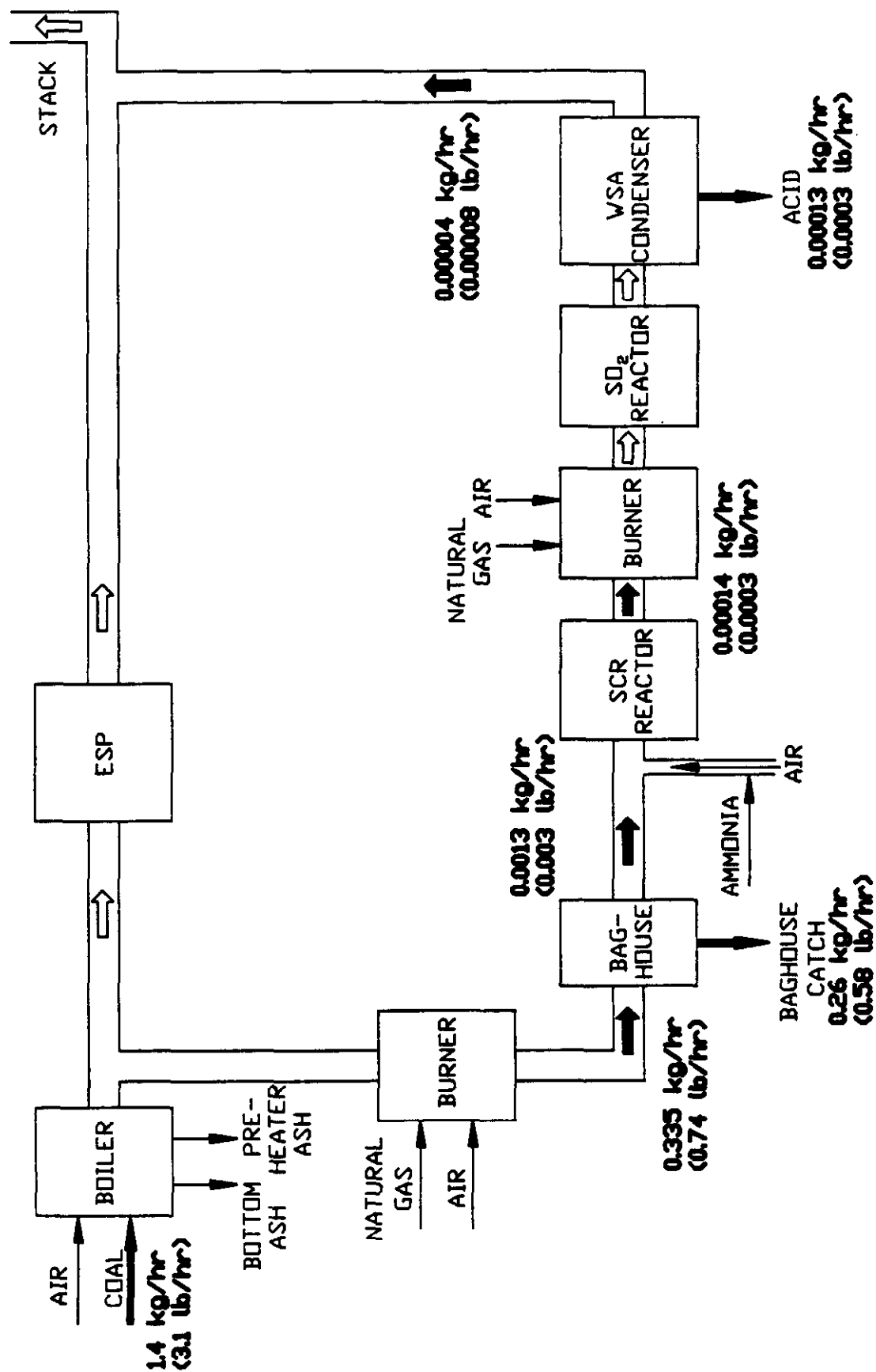


Figure 6-5. Arsenic balance for SNOX system

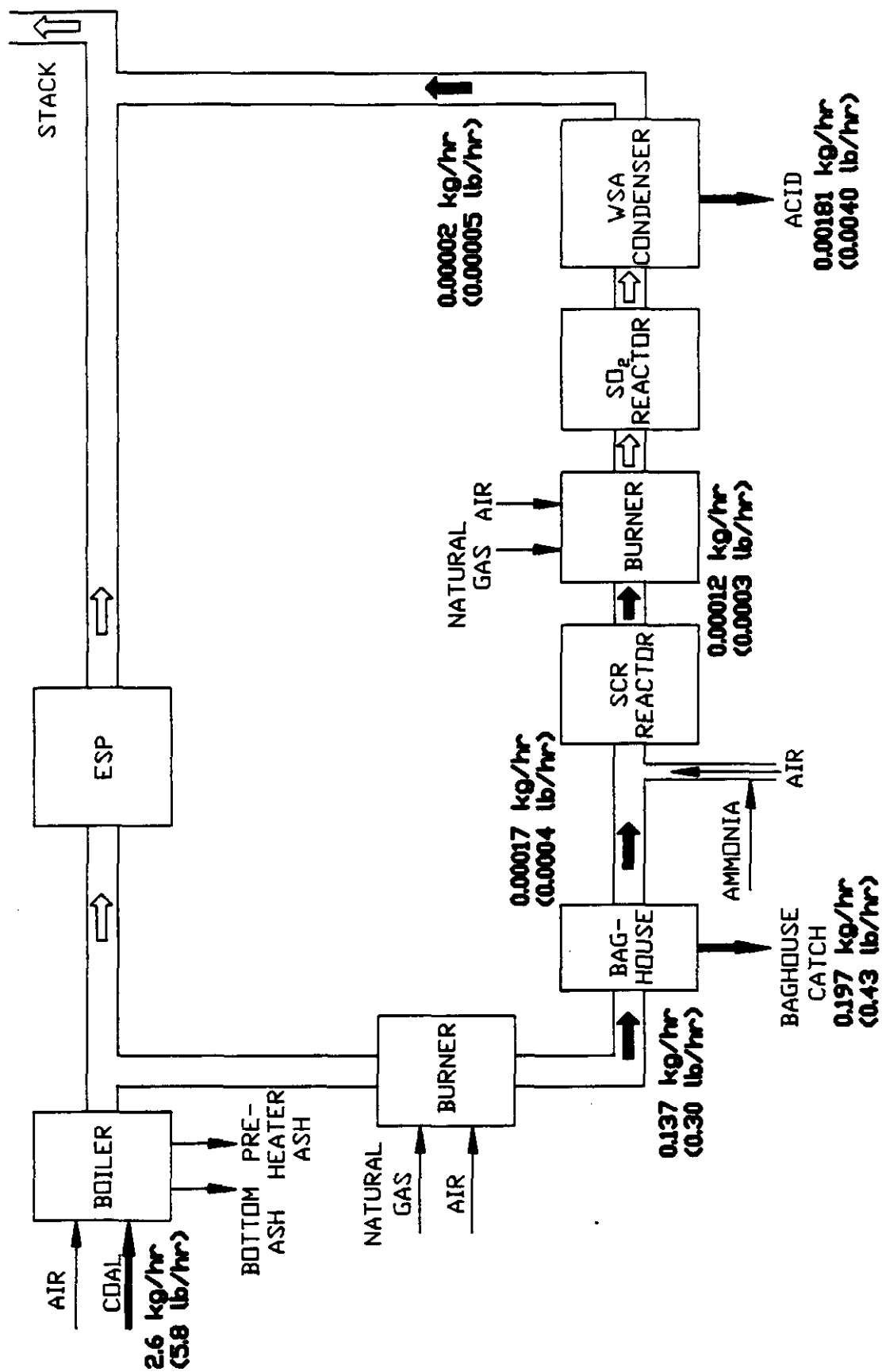


Figure 6-6. Barium balance for SNOX system

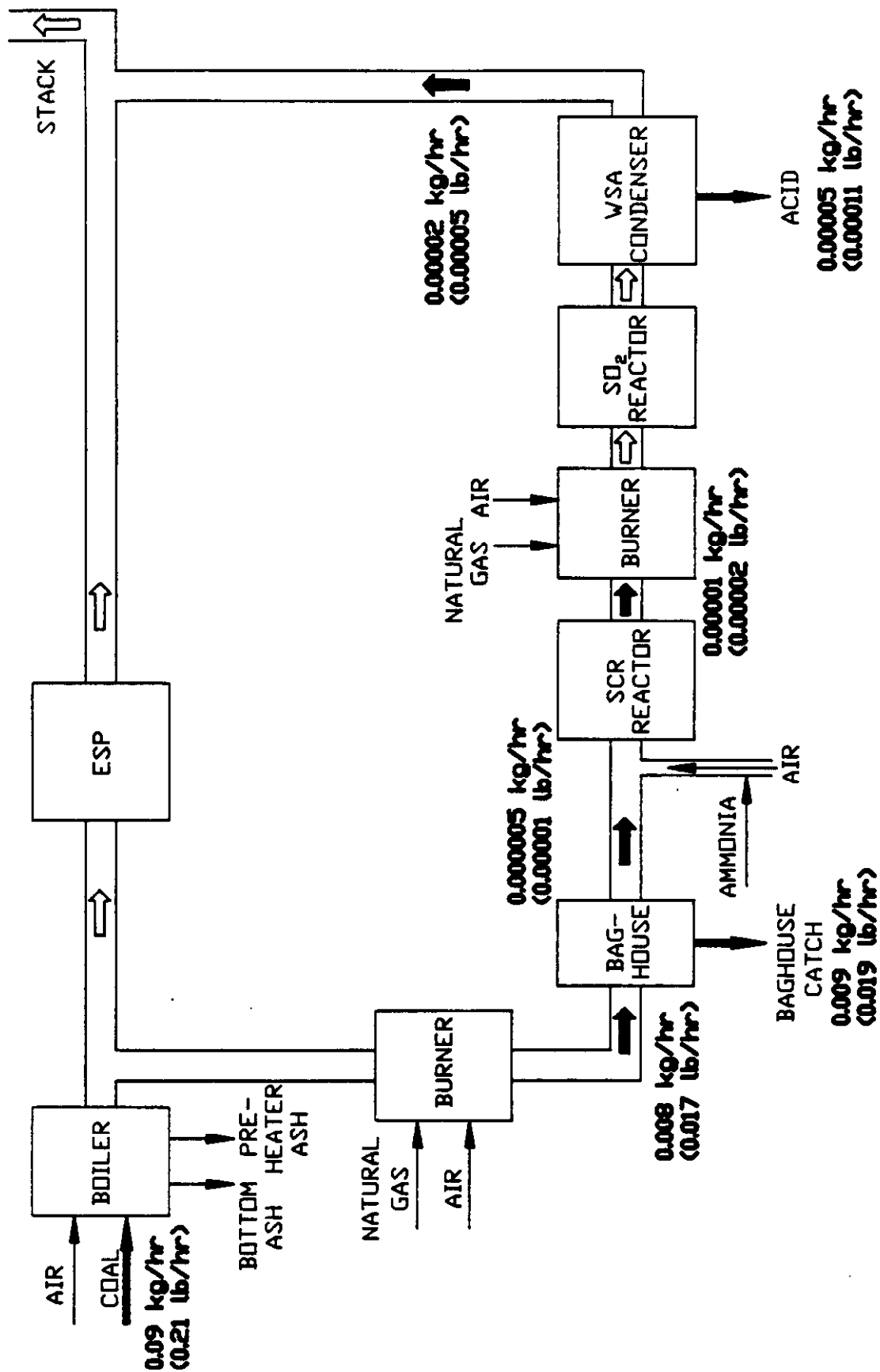


Figure 6-7. Beryllium balance for SNOX system

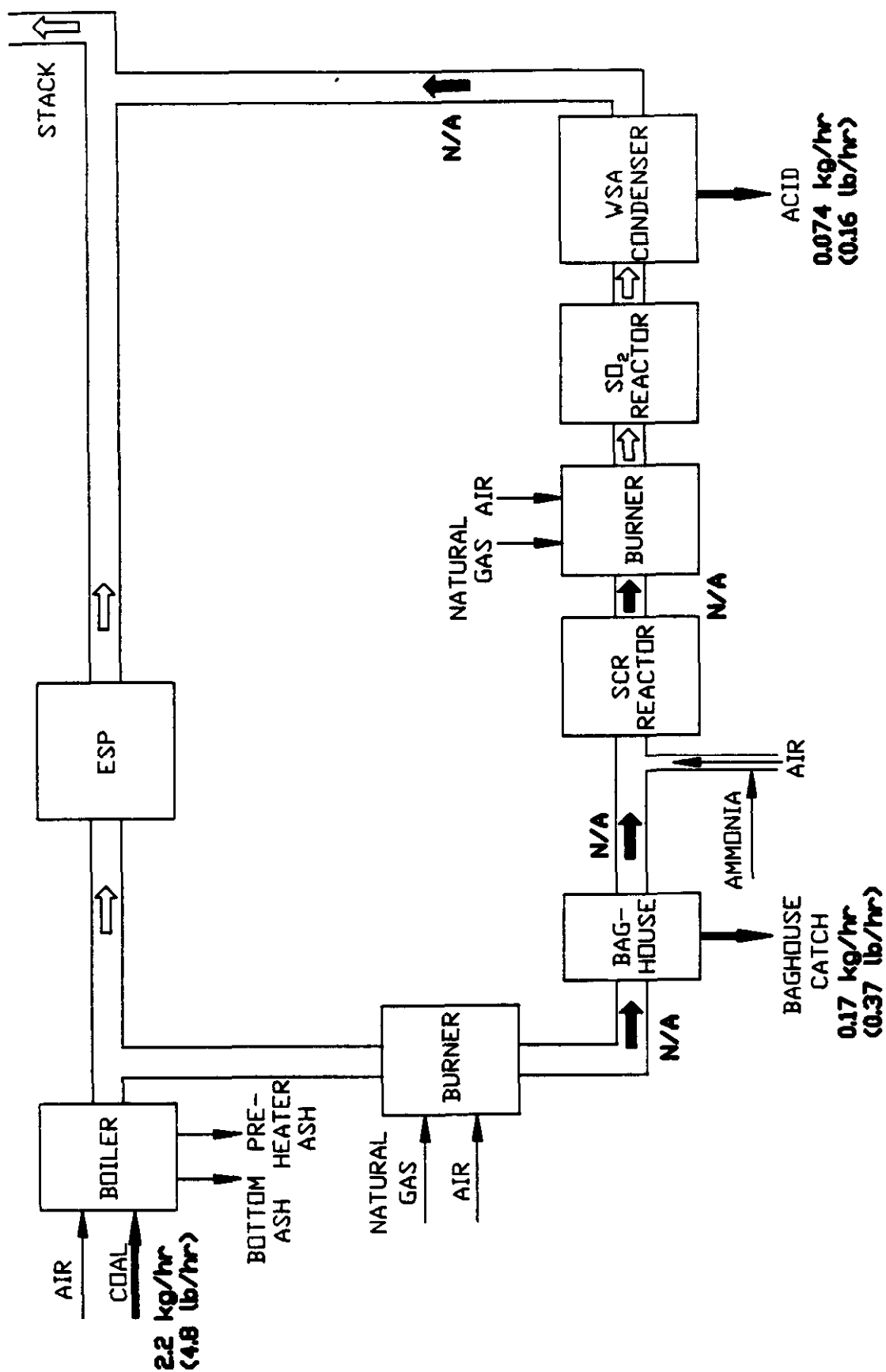


Figure 6-8. Boron balance for SNOX system

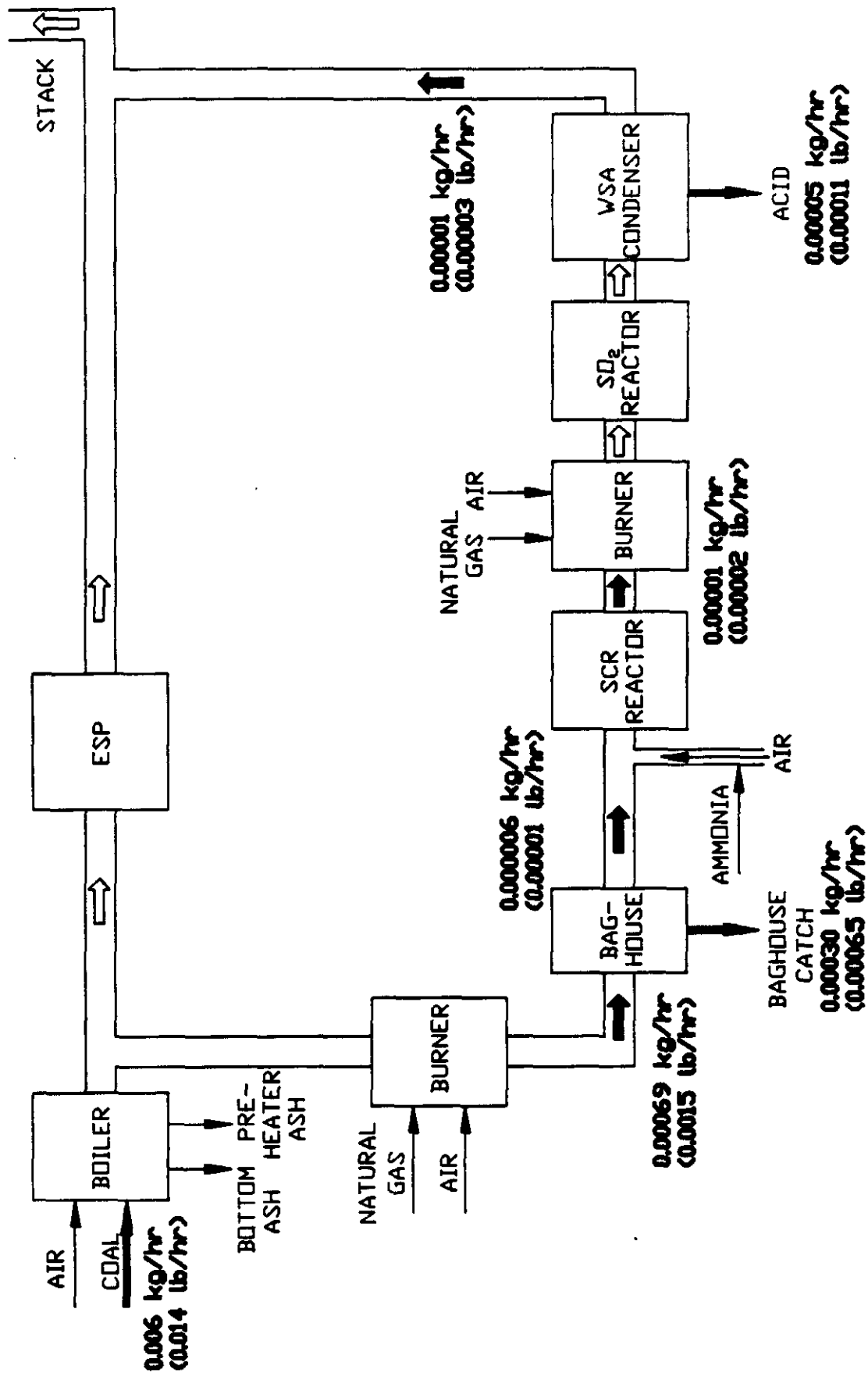


Figure 6-9. Cadmium balance for SNOX system

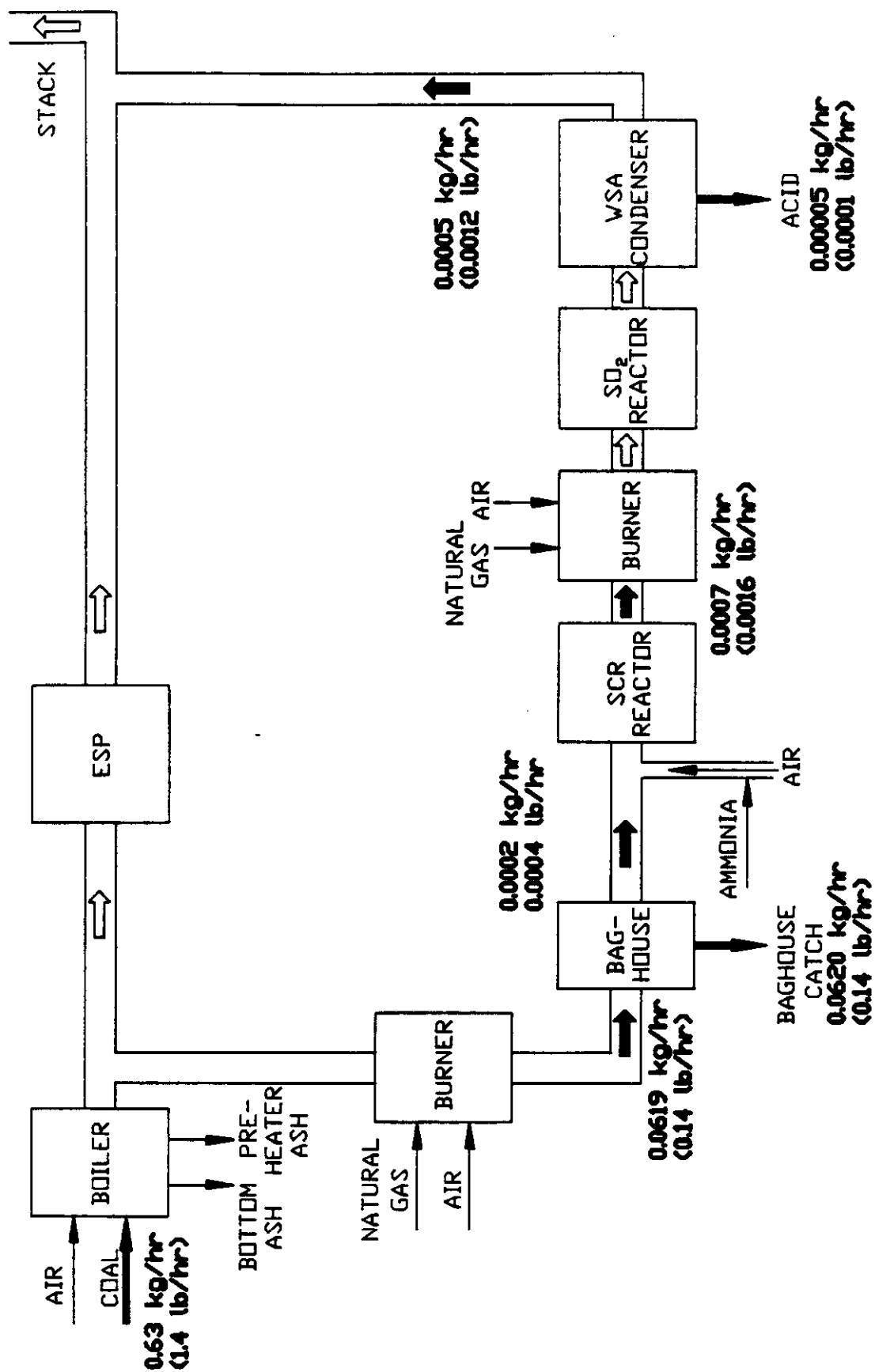


Figure 6-10. Chromium balance for SNOX system

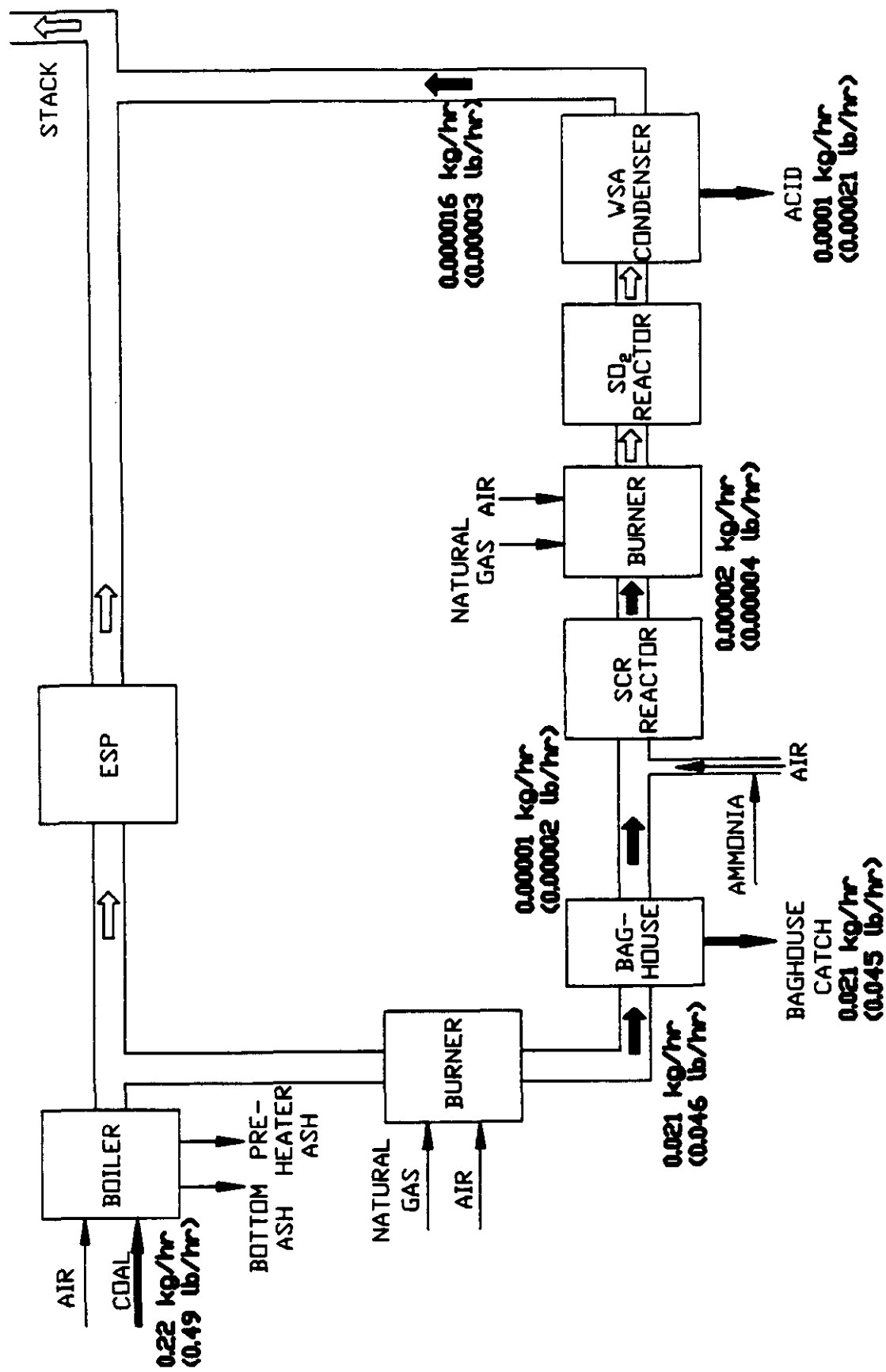


Figure 6-11. Cobalt balance for SNOX system

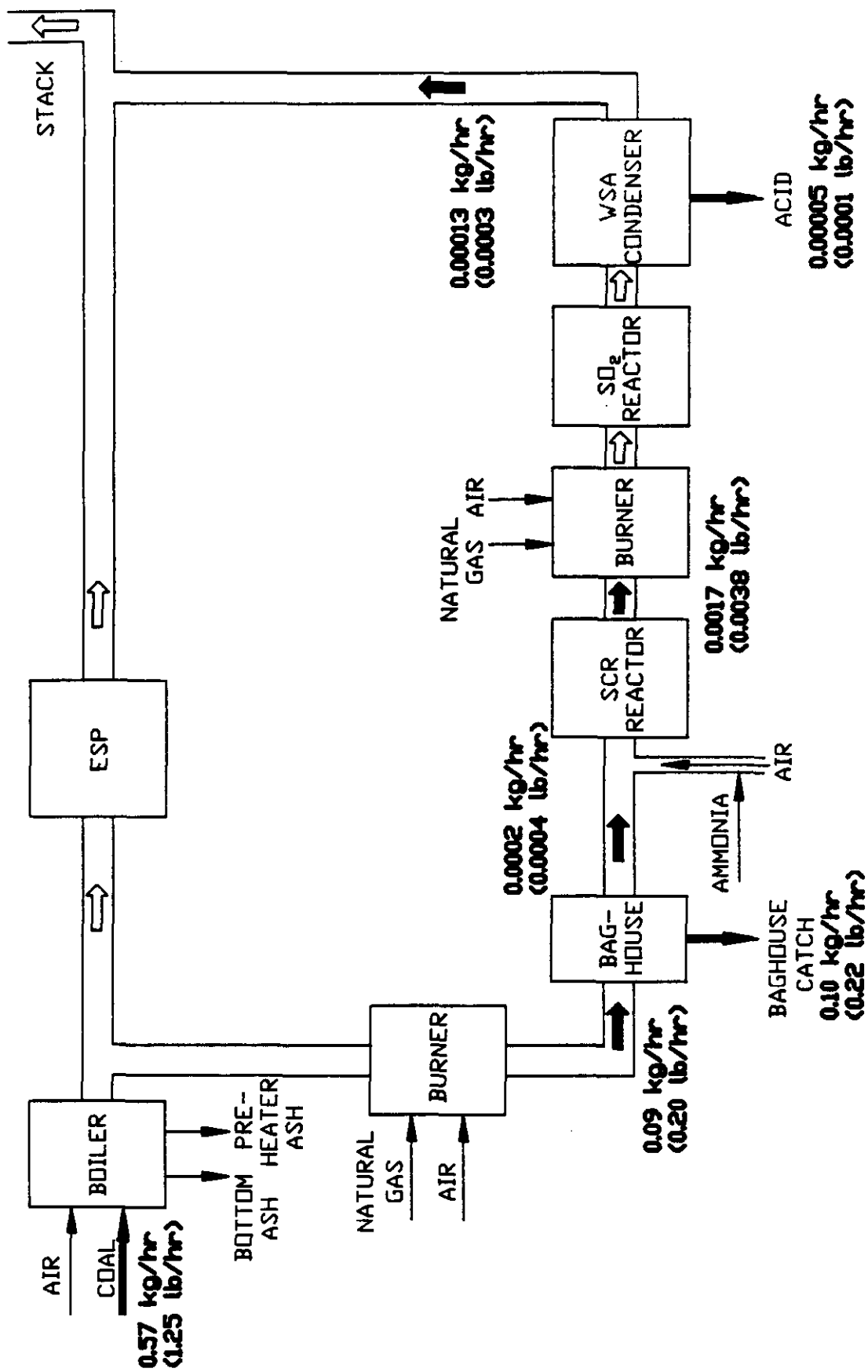


Figure 6-12. Copper balance for SNOX system

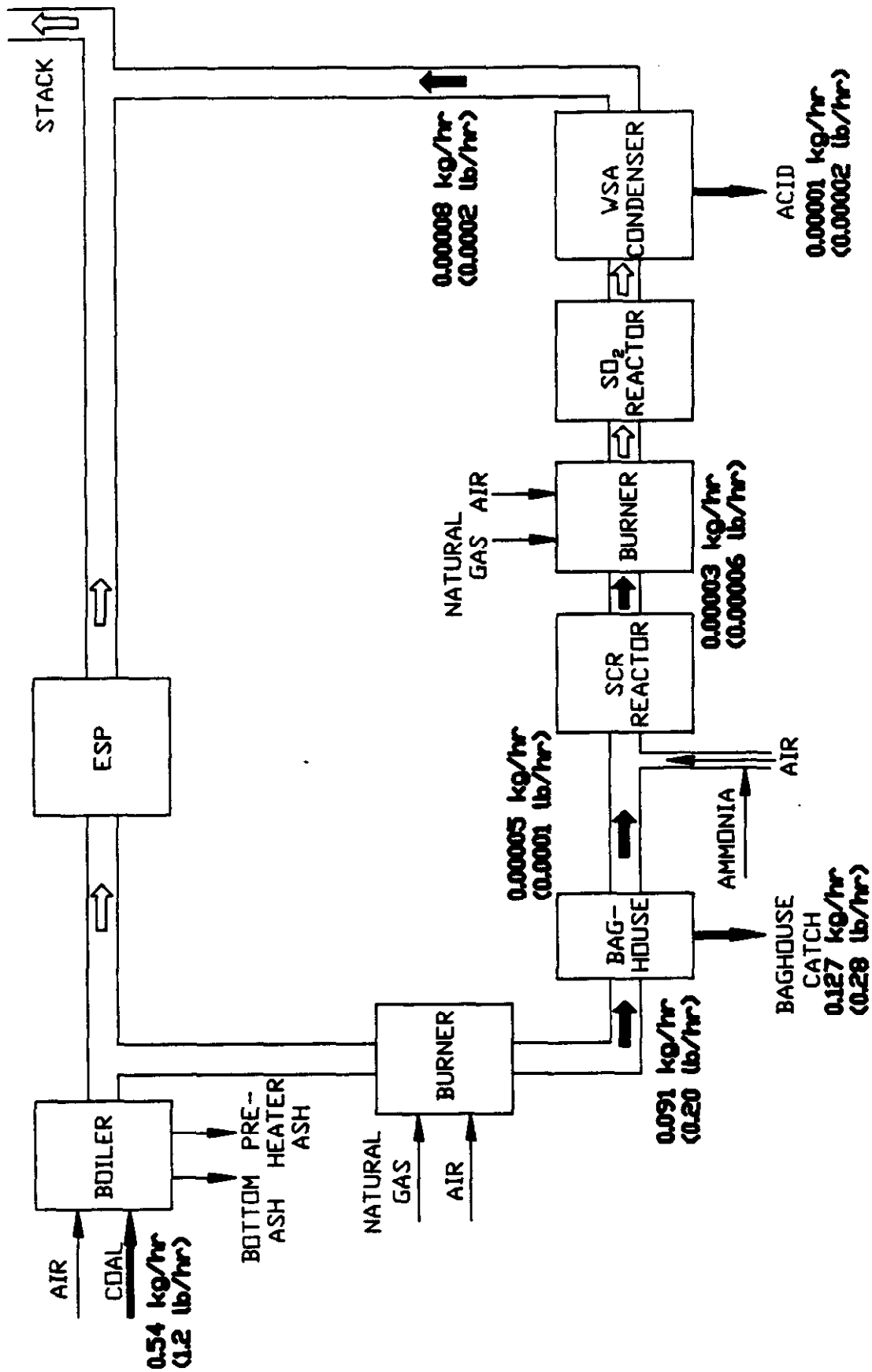


Figure 6-13. Lead balance for SNOX system

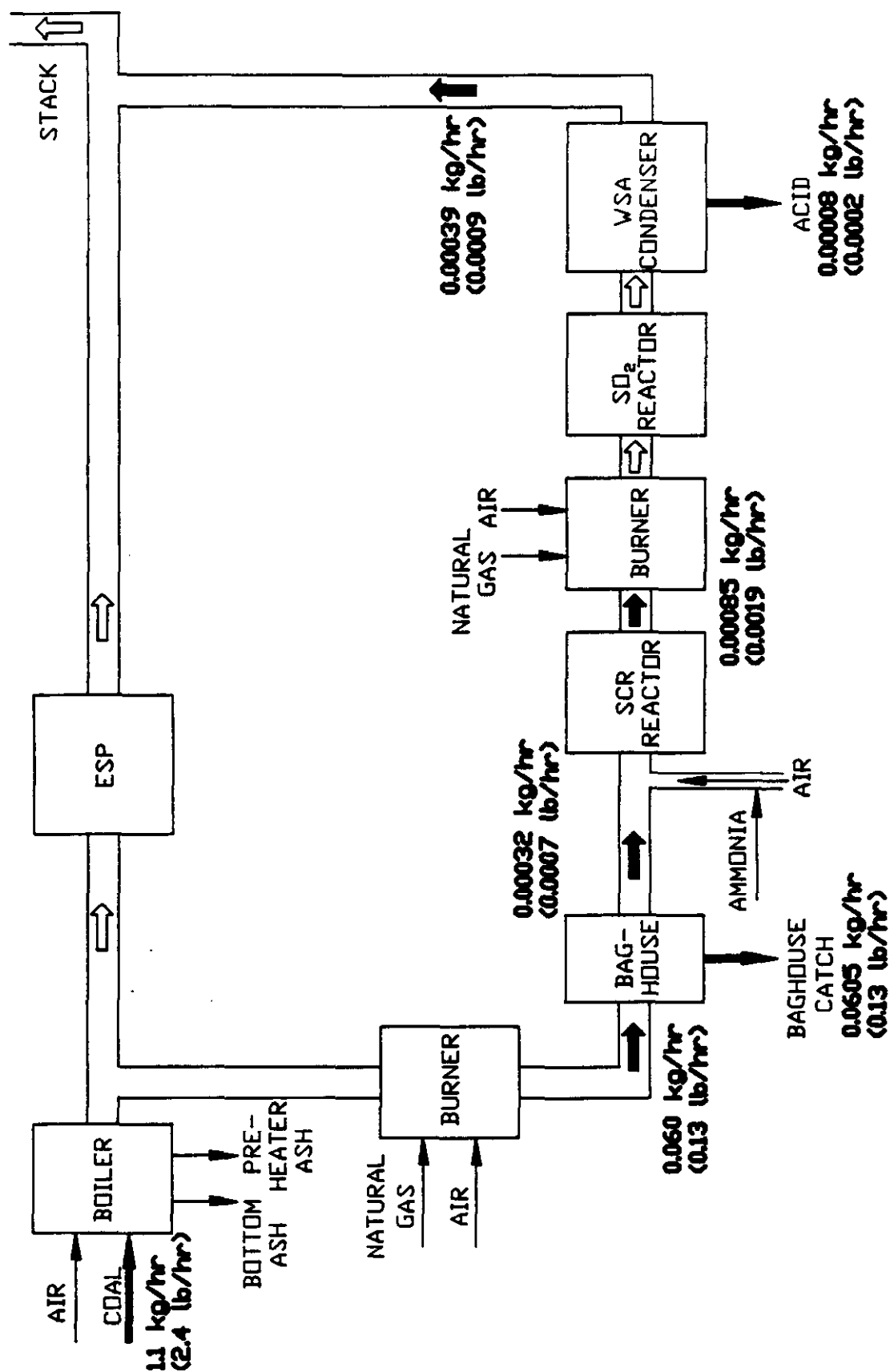


Figure 6-14. Manganese balance for SNOX system

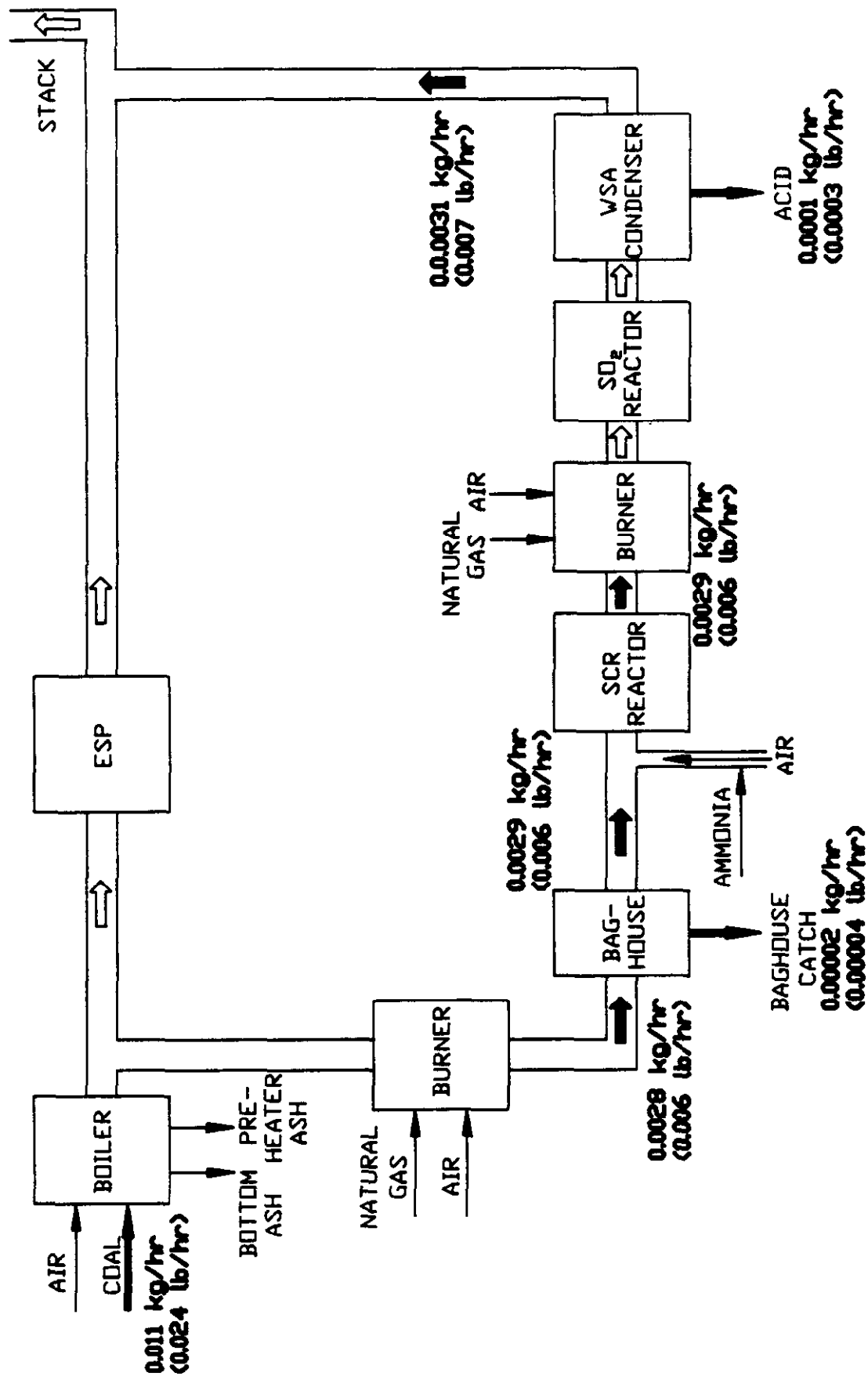


Figure 6-15. Mercury balance for SNOX system

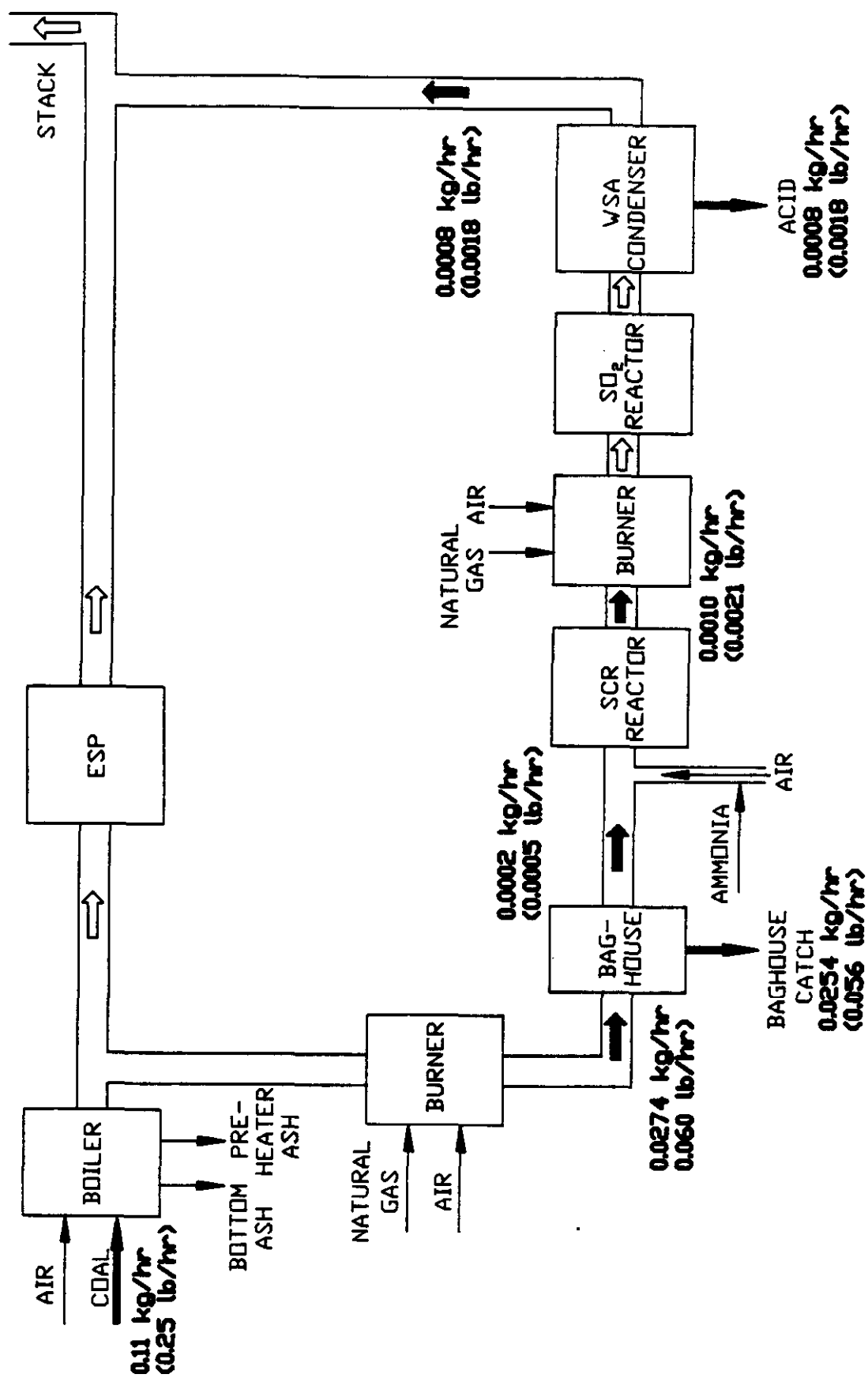


Figure 6-16. Molybdenum balance for SNOX system

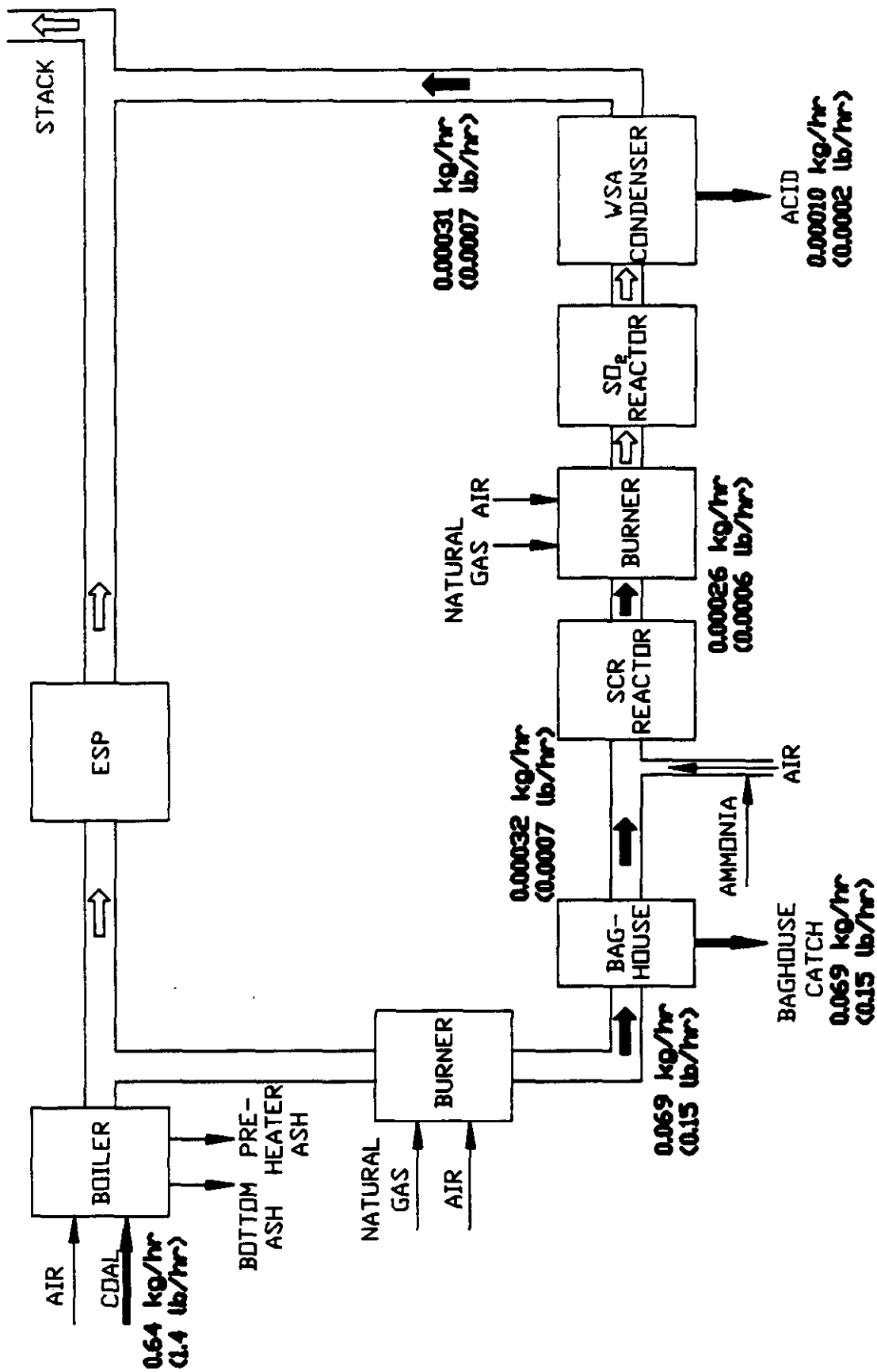


Figure 6-17. Nickel balance for SNOX system

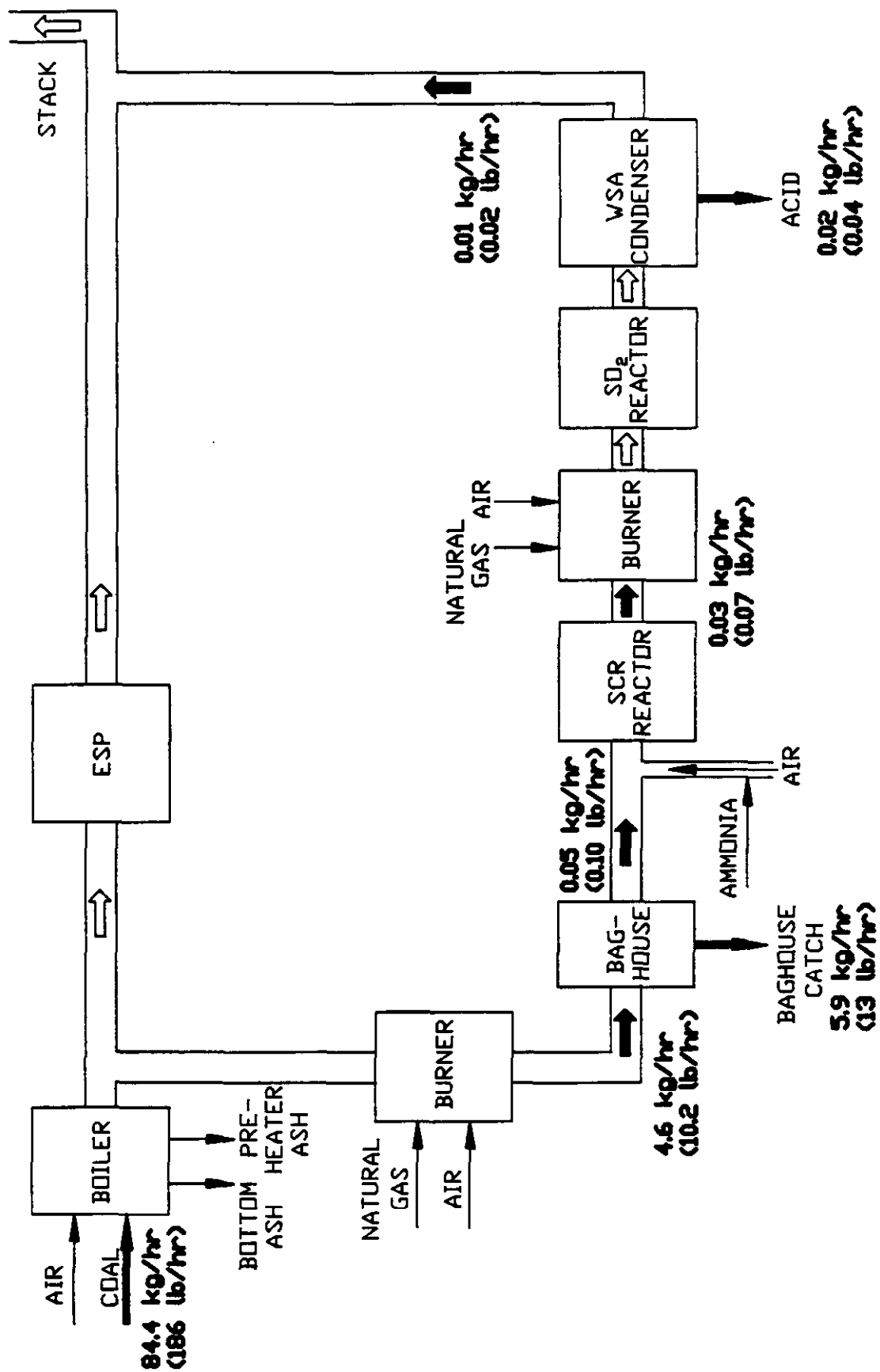


Figure 6-18. Potassium balance for SNOX system

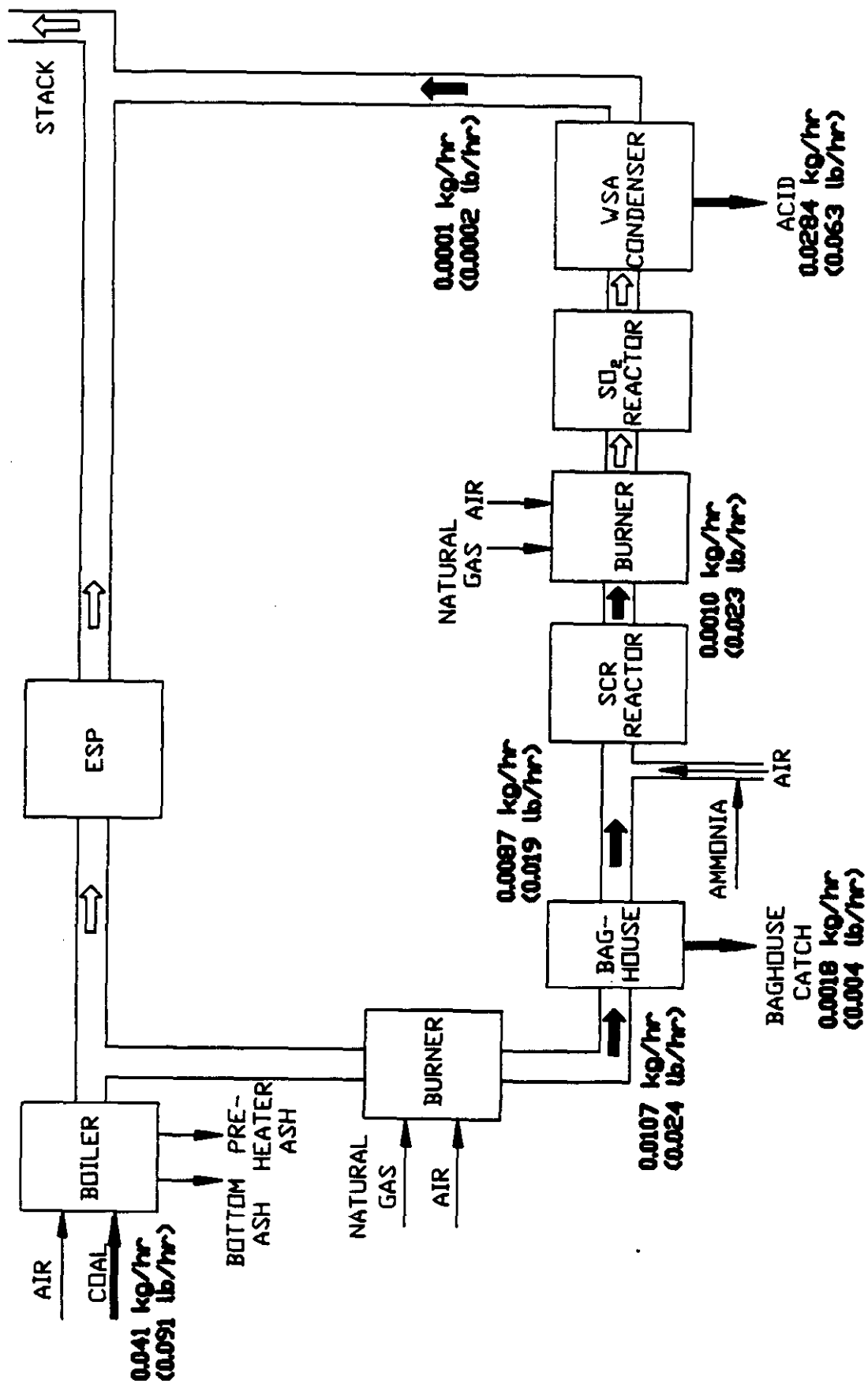


Figure 6-19. Selenium balance for SNOX system

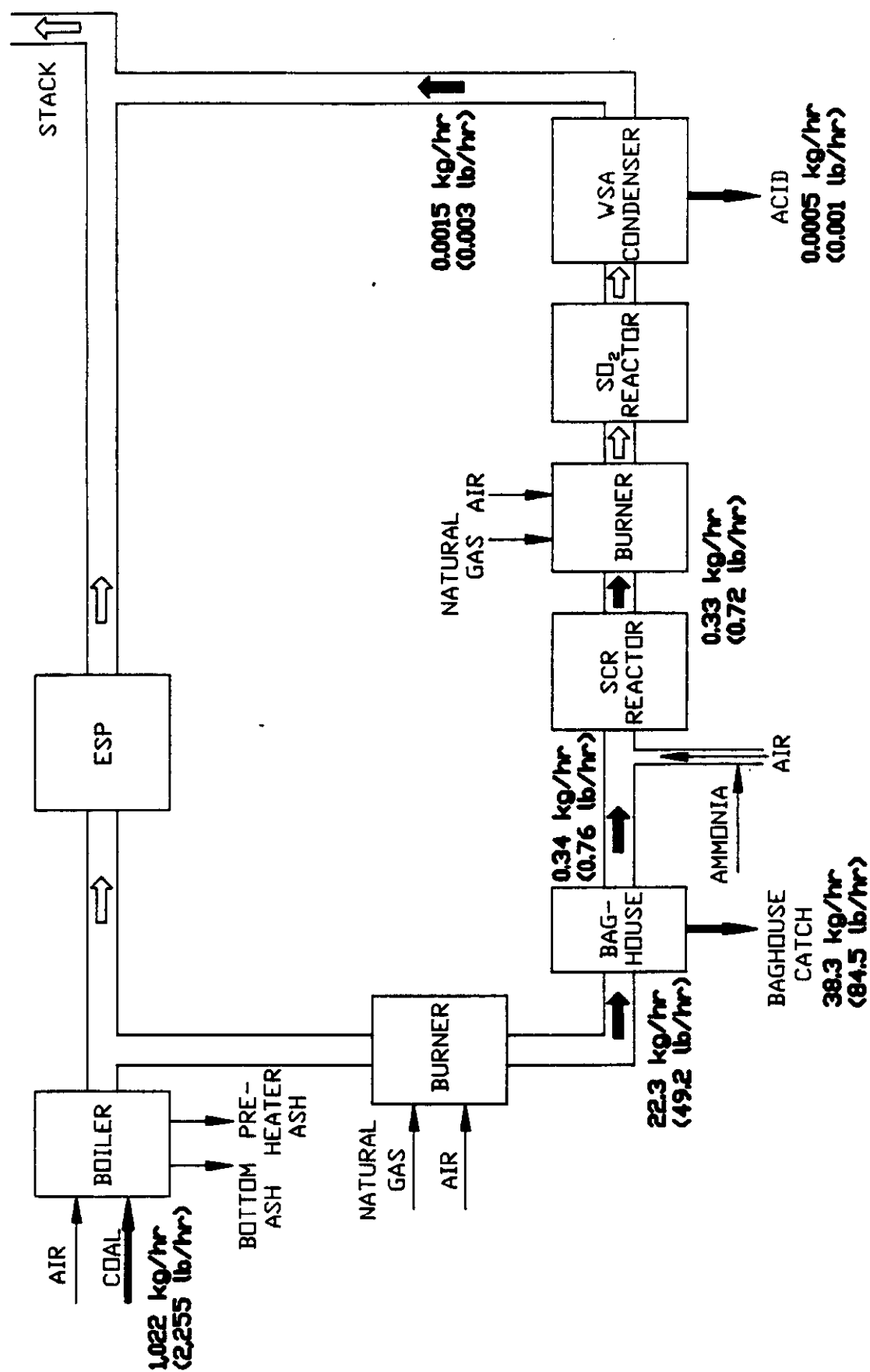


Figure 6-20. Silicon balance for SNOX system

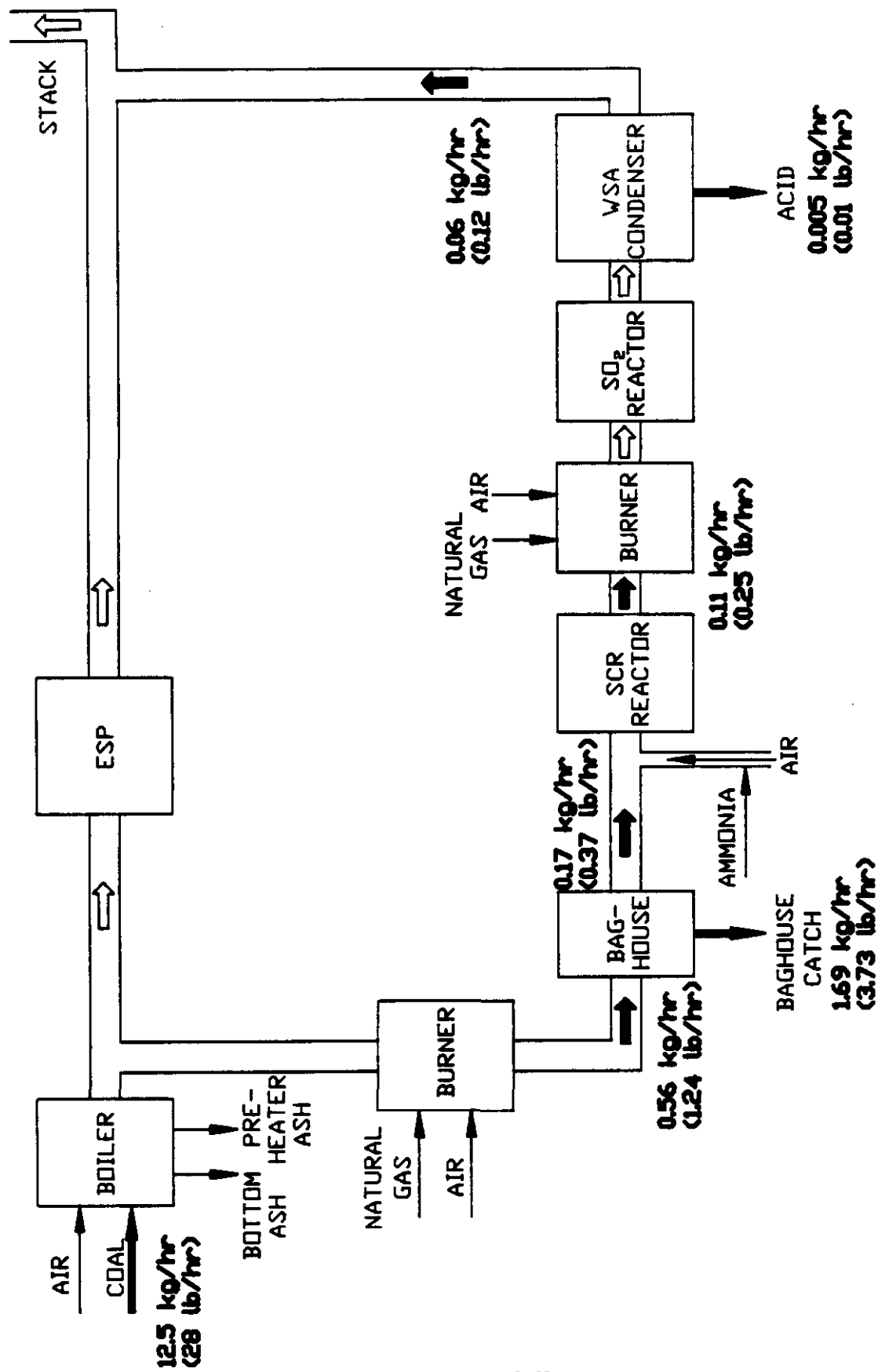


Figure 6-21. Sodium balance for SNOX system

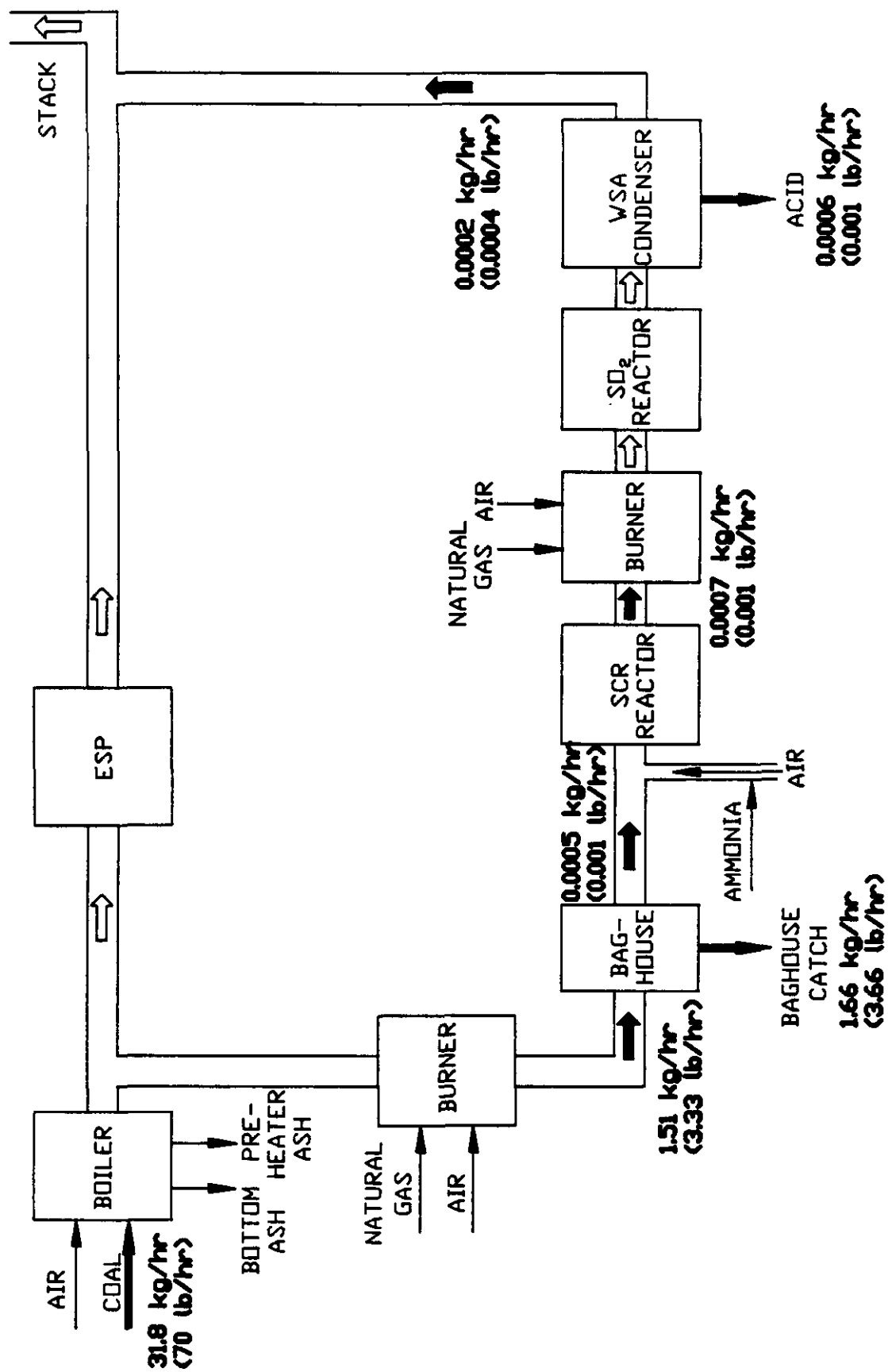


Figure 6-22. Titanium balance for SNOX system

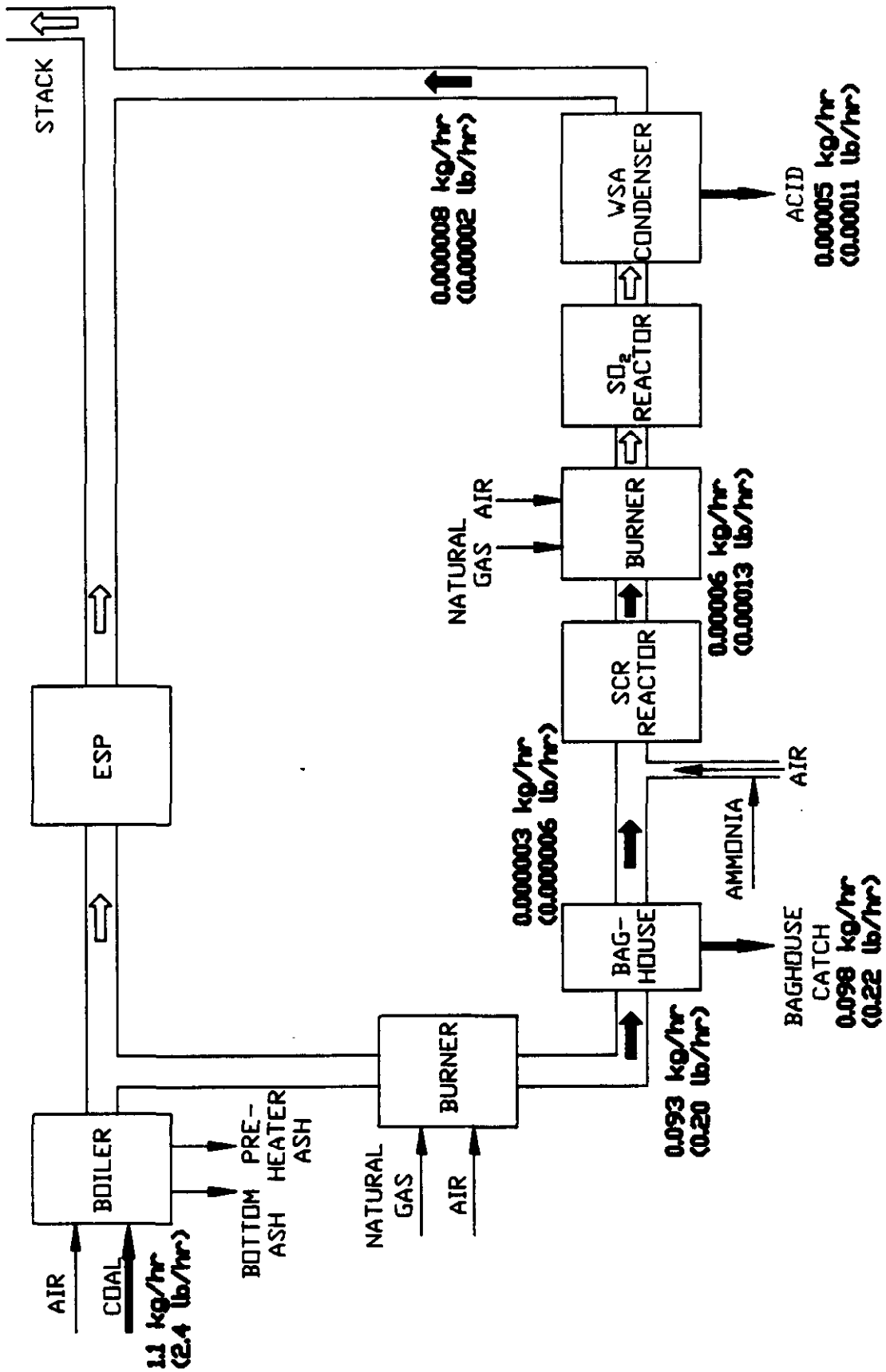


Figure 6-23. Vanadium balance for SNOX system

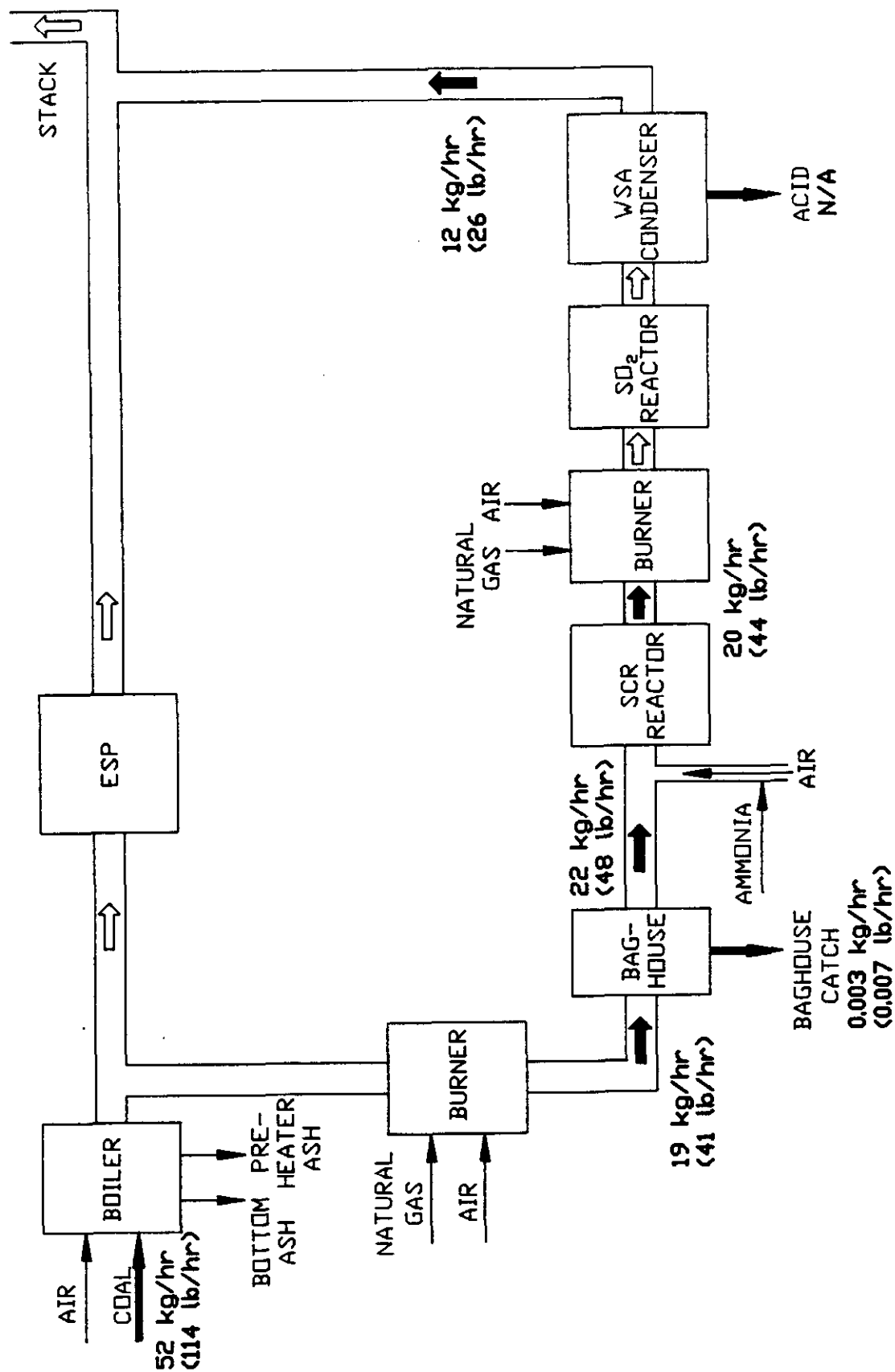


Figure 6-24. Chlorine balance for SNOX system

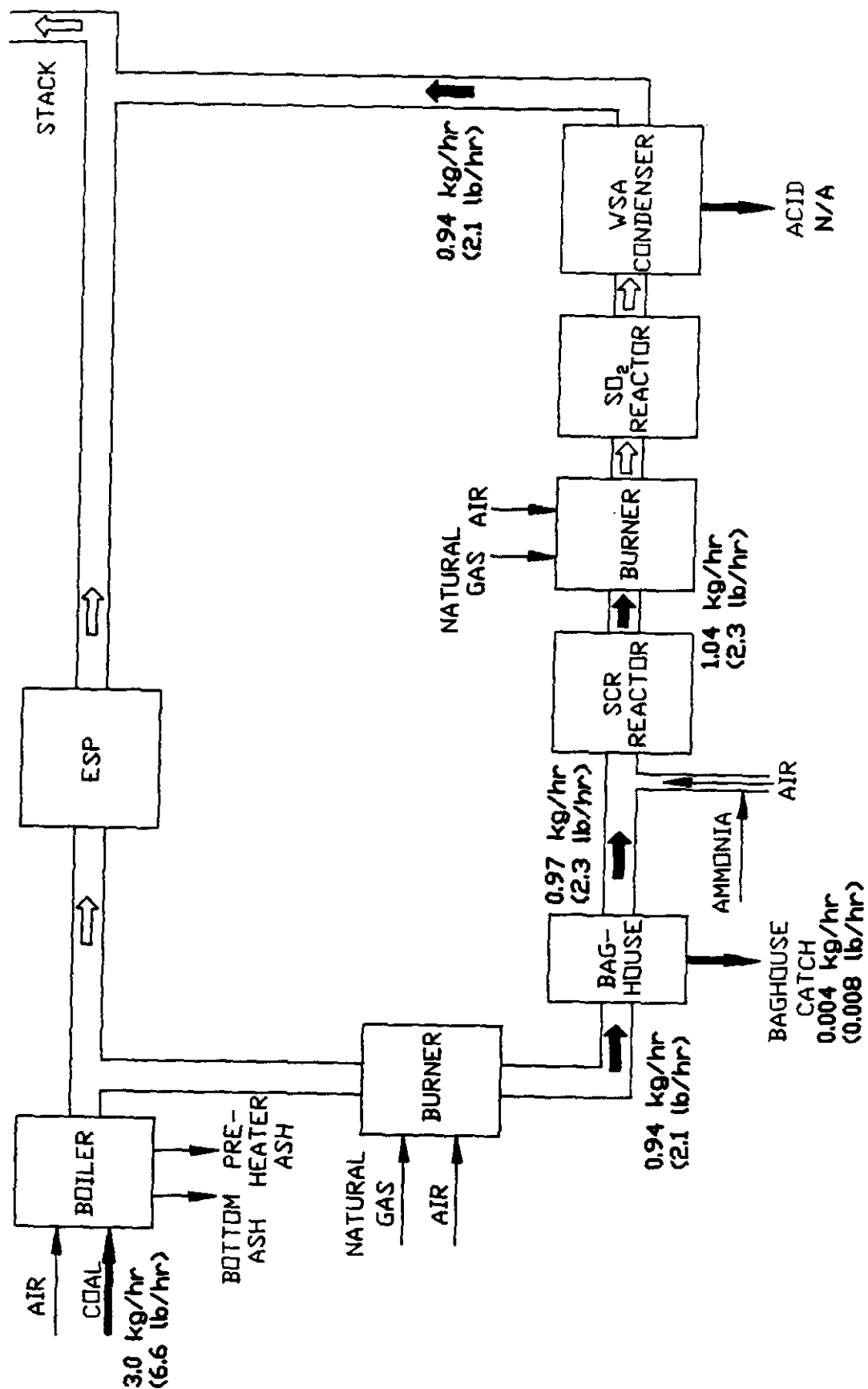


Figure 6-25. Fluorine balance for SNOX system

7.0 SPECIAL TOPICS

In addition to sampling conducted to determine emission factors and removal efficiencies of HAPs, four special topics related to sampling and analysis of HAPs were investigated. These special topics are:

- Distribution of semivolatile substances between the vapor and particle phases
- Particle size distribution of elements in flue gas streams
- Comparison of the HEST and Method 29 methods for measuring mercury, selenium and arsenic in flue gas
- Comparison of canister and VOST techniques for measuring concentrations of VOC in flue gas streams

Results of these investigations are described in this part of the report.

7.1 Vapor/Particulate Comparisons

This section discusses the distribution of selected substances between the vapor and particulate phases in flue gas samples. As detailed earlier in this report, samples were collected from flue gas streams at the: (1) baghouse inlet - Location 18, (2) baghouse outlet - Location 19, (3) SCR reactor outlet - Location 20, and (4) WSA tower outlet - Location 21. The sampling methods used at these locations separated the vapor and particulate phases of selected HAPs that were present in the flue gas streams so as to allow separate analyses of the concentrations in the two phases.

Vapor and particulate phase samples collected from the various sampling locations were analyzed individually for elements and PAH and other SVOC. The results of these analyses are presented in this section. For each group of species, the vapor and particulate phase concentrations of individual HAPs, corrected for field blanks, are presented. Concentration data are provided separately for each of the four flue gas sampling locations. For each group of species, the vapor and particulate phase concentrations measured in blank gas samples and/or method blanks are also presented.

The phase distribution results are discussed briefly for each group of species. Differences in phase distribution of individual HAPs among the various sampling locations are examined. The potential for sampling artifacts to arise during the separation of the vapor and particulate phases is noted where applicable.

Each sub-section also presents a table of the average distribution of individual species concentrations between the vapor and particulate phases in the flue gas at the various sampling locations. This table provides a summary of the differences in composition of the vapor and particulate phases.

7.1.1 Elements

Table 7.1-1 shows a summary of the average phase distribution of elements at each sampling location. The data in Table 7.1-1 were derived by averaging the phase distributions measured in the sets of three samples collected at each location; zero values were used for vapor or particulate elemental concentrations that were below the detection limit in any sample. The vapor and particulate phase concentrations (in $\mu\text{g}/\text{Nm}^3$) of elements determined from flue gas samples are presented in Tables 7.1-2 through 7.1-5. Table 7.1-6 shows the corresponding vapor and particulate phase concentrations of the individual elements in train blank samples.

The vapor and particulate phase concentrations (in $\mu\text{g}/\text{Nm}^3$) of mercury in the flue gas samples collected at various sampling locations are also presented in Tables 7.1-2 through 7.1-5. Table 7.1-6 shows the corresponding vapor and particulate phase concentrations of mercury in the train blank samples. Table 7.1-1 shows the average phase distributions of mercury at each location, along with those for all the other elements.

Tables 7.1-1 and 7.1-2 show that at Location 18, the baghouse inlet, all the elements, except for mercury, were present almost entirely in the particulate phase, with little variability among the three samples (evidenced by the low standard deviations in Table 7.1-1). The table also reveals that at Location 18, mercury is predominantly (>94 percent) present in the vapor phase, results which are consistent with the vapor pressure characteristics of mercury.

TABLE 7.1-5. VAPOR/PARTICULATE DISTRIBUTION FOR ELEMENTS FROM WSA CONDENSER OUTLET (LOCATION 21) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-21-MUM-719			N-21-MUM-722			N-21-MUM-724		
	VAPOR	SOLID	TOTAL	VAPOR	SOLID	TOTAL	VAPOR	SOLID	TOTAL
Aluminum	0.00	475	475	0.00	0.00	0.00 #	0.00	181	181
Potassium	0.00	267	267	0.00	0.00	0.00	0.00	47.6	47.6
Silicon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sodium	0.00	631	631	0.00	0.00	0.00 #	0.00	345	345
Titanium	0.00	3.60	3.60	0.00	0.00	0.00	0.00	1.43	1.43
Antimony	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arsenic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barium	0.00	0.518	0.518	0.00	0.00	0.00	0.00	0.00	0.00
Beryllium	0.194	0.00	0.194	0.0701	0.00	0.0701	0.00	0.00	0.00
Boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	0.0486	0.00	0.0486	0.00	0.00	0.00	0.00	0.00	0.00
Chromium	2.14	2.15	4.29	0.935	71.8 *	72.8 #	0.912	5.56	6.47
Cobalt	0.00	0.00	0.00	0.00	0.830	0.830 #	0.00	0.00	0.00
Copper	0.389	1.09	1.48	1.05	0.21	1.26	0.570	0.00	0.570
Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.810	0.810
Manganese	1.75	0.699	2.45	0.00	5.19	5.19	2.05	0.793	2.85
Mercury	35.3	0.859	36.2	21.1	0.816	21.9	27.1	3.43	30.5
Molybdenum	0.00	6.68	6.68	0.00	8.09	8.09	0.00	5.09	5.09
Nickel	0.680	0.00	0.680	0.00	32.8 *	32.8 #	0.228	4.46	4.68
Selenium	0.486	0.518	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Vanadium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NC = Not calculated.

NA = Sample not available, sample not analyzed, or data not available.

Silicon missing from filter and cyclone analyses.

Possible contamination of aluminum, potassium, and sodium in filter analyses.

Sample results corrected for N-21-MUM-718 train blank.

* These values are believed to result from contamination by stainless steel. Molybdenum may also have been affected on this day.

= Outlier value (see Section 5), not used in calculations.

TABLE 7.1-6. VAPOR/PARTICULATE DISTRIBUTION FOR ELEMENTS IN BLANK GAS SAMPLES (LOCATION 21) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-21-MUM-718		
	VAPOR	SOLID	TOTAL
Aluminum	3740	3070	6810
Potassium	2420	1890	4310
Silicon	1110	9390	10500
Sodium	6000	4500	10500
Titanium	9.17	8.52	17.7
Antimony	0.00	0.00	0.00
Arsenic	0.00	0.00	0.00
Barium	5.65	10.3	15.9
Beryllium	0.00	0.00	0.00
Boron	NA	NA	NA
Cadmium	0.00	0.00	0.00
Chromium	0.00	0.621	0.621
Cobalt	0.00	0.00	0.00
Copper	0.00	3.60	3.60
Lead	0.00	0.00	0.00
Manganese	0.853	0.757	1.61
Mercury	0.196	0.054	0.250
Molybdenum	1.07	1.51	2.58
Nickel	0.00	0.00	0.00
Selenium	0.00	0.946	0.946
Vanadium	0.00	0.00	0.00

NA = Sample not available, sample not analyzed, or data not available.
 Silicon missing from filter and cyclone analyses.
 Possible contamination of aluminum, potassium, and sodium in filter analyses.

Table 7.1-7. Summary of average phase distributions of PAH/SVOC at each sampling location.

SPECIES	Percentage Phase Distribution; P: Particulate; V: Vapor														
	Location 18			Location 19			Location 20			Location 21					
	P	V	±SD	P	V	±SD	P	V	±SD	P	V	±SD	P	V	±SD
PAH/SVOC															
Benzylchloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	66.7	33.3	57.7			
Acetophenone	1.6	98.4	1.1	10.2	89.8	17.7	ND	ND	ND	0	100	0			
Hexachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
Naphthalene	3.6	96.4	3.1	64.1	35.9	52.8	53.2	46.8	49.1	2	98	1.3			
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
2-Chloroacetophenone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
1-Methylnaphthalene	7.4	92.6	6.1	23.3	76.7	26.4	48.4	51.6	48.4	4.9	95.1	3.1			
2-Methylnaphthalene	8.3	91.7	7.9	31	69	26.1	44.6	55.4	50.9	2.1	97.9	2.3			
Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
Biphenyl	5.7	94.3	6.1	57.6	42.4	51	91.1	8.9	10.1	75.3	24.7	42.9			
Acenaphthylene	34.6	65.2	56.4	15.3	84.7	9.3	ND	ND	ND	0.8	99.2	1.5			
2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
Acenaphthene	5.6	94.4	2.6	33.6	66.4	53	ND	ND	ND	0	100	0			
Dibenzofuran	9.3	90.7	6.1	22.7	77.3	34.6	75.9	24.1	41.8	8.3	91.7	1.7			
2,4-Dinitrotoluene	39.1	60.9	53.4	0	100	0	ND	ND	ND	ND	ND	ND			
Fluorene	9.3	90.7	10.1	32.8	67.2	46.7	ND	ND	ND	ND	ND	ND			
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			
Phenanthrene	4.4	95.6	4.8	17.6	82.4	24.3	ND	ND	ND	ND	ND	ND			
Anthracene	4.4	95.6	4.5	29.8	70.2	29.5	70	30	52	16.3	83.7	11.8			
Fluoranthene	3.6	96.4	4.9	41.3	58.7	24.3	ND	ND	ND	15.1	84.9	2.7			
Pyrene	4.2	95.8	5.9	100	0	0	66.7	33.3	57.7	100	0	0			
Benz(a)anthracene	3.1	96.9	4	36.1	63.9	55.5	-	-	-	41	59	51.2			
Chrysene	2.9	97.1	3.3	25	75	22.5	35.1	64.9	56.3	36.7	63.3	55			
Benzo(b & k)fluoranthene	4	96	4.9	ND	ND	ND	64.8	35.2	39.6	45.1	54.9	47.9			
Benzo(e)pyrene	34.4	65.6	56.9	-	-	-	100	0	-	74.9	25.1	43.4			
Benzo(a)pyrene	-	-	-	100	0	0	100	0	-	-	-	-			
Indeno(1,2,3-c,d)pyrene	-	-	-	100	0	0	100	0	-	-	-	-			
Dibenzo(a,h)anthracene	100	0	0	100	0	-	100	0	-	-	-	-			
Benzo(g,h,i)perylene	100	0	-	100	0	-	100	0	-	-	-	-			

P, V, SD: Averages and standard deviation derived from the three samples at each location

ND: Not detected in all three samples at this location

-: Not detected in two of three samples at this location or otherwise not interpretable (see text)

TABLE 7.1-8. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC FROM BAGHOUSE INLET (LOCATION 18) (ng/Nm³)

Analyte	N-18-MM5- X-718	N-18-MM5- F-718	N-18-MM5- F+X-718	N-18-MM5- X-721	N-18-MM5- F-721	N-18-MM5- F+X-721	N-18-MM5- X-723	N-18-MM5- F-723	N-18-MM5- F+X-723
Benzylchloride	ND < 17.2	ND < 0.862	ND < 17.2	ND < 19.8	ND < 0.988	ND < 19.8	ND < 18.4	ND < 0.919	ND < 18.4
Acetophenone	640	17.4	657	838	12.7	850	299	1.58	301
Hexachloroethane	ND < 17.2	ND < 0.862	ND < 17.2	ND < 19.8	ND < 0.988	ND < 19.8	ND < 18.4	ND < 0.919	ND < 18.4
Naphthalene	476	8.84	485	305	5.57	311	123	9.50	132
Hexachlorobutadiene	ND < 17.2	ND < 0.862	ND < 17.2	ND < 19.8	ND < 0.988	ND < 19.8	ND < 18.4	ND < 0.919	ND < 18.4
2-Chloroacetophenone	ND < 17.2	ND < 0.862	ND < 17.2	ND < 19.8	ND < 0.988	ND < 19.8	ND < 18.4	ND < 0.919	ND < 18.4
2-Methylnaphthalene	139	5.46	145	103	4.33	107	28.1	4.76	32.9
1-Methylnaphthalene	73.7	3.09	76.8	49.4	1.75	51.1	14.8	3.11	17.9
Hexachlorocyclopentadiene	ND < 17.2	ND < 0.862	ND < 17.2	ND < 19.8	ND < 0.988	ND < 19.8	ND < 18.4	ND < 0.919	ND < 18.4
Biphenyl	220	3.58	224	157	4.33	162	21.1	3.08	24.2
Acenaphthylene	31.1	0.940	32.1	15.7	0.245	15.9	ND < 3.67	0.374	0.374
2,6-Dinitrotoluene	ND < 17.2	38.5	38.5	ND < 19.8	ND < 0.988	ND < 19.8	ND < 18.4	22.0	22.0
Acenaphthene	53.6	3.37	57.0	76.6	2.27	78.9	21.2	1.88	23.1
Dibenzofuran	212	10.4	222	129	6.21	135	37.3	8.56	45.8
2,4-Dinitrotoluene	21.1	4.44	25.5	61.9	ND < 0.988	61.9	ND < 18.4	1.92	1.92
Fluorene	176	6.27	182	88.4	3.18	91.6	13.4	3.54	17.0
Hexachlorobenzene	ND < 17.2	ND < 0.862	ND < 17.2	ND < 19.8	ND < 0.988	ND < 19.8	ND < 18.4	ND < 0.919	ND < 18.4
Pentachlorophenol	ND < 17.2	ND < 0.862	ND < 17.2	ND < 19.8	ND < 0.988	ND < 19.8	ND < 18.4	ND < 0.919	ND < 18.4
Phenanthrene	2430 E	36.9	2470 E	769	14.1	783	177	19.5	197
Anthracene	176	1.89	178	40.3	1.08	41.4	8.72	0.917	9.64
Fluoranthene	4630 E	39.6	4670 E	587	4.66	592	68.8	7.03	75.8
Pyrene	1350 E	5.29	1360 E	164	1.87	166	21.4	2.64	24.0
Benz(a)anthracene	863	7.81	871	98.2	0.683	98.8	5.10	0.427	5.52
Chrysene	2970 E	44.2	3020 E	402	2.46	405	39.2	2.83	42.0
Benzo(b & k)fluoranthene	534	5.40	539	90.3	1.21	91.5	10.3	1.10	11.4
Benzo(e)pyrene	88.9	1.02	89.9	16.5	0.324	16.8	ND < 3.67	0.311	0.311
Benzo(a)pyrene	6.83	0.616	7.44	ND < 3.95	ND < 0.198	ND < 3.95	ND < 3.67	ND < 0.184	ND < 3.67
Indeno(1,2,3-c,d)pyrene	ND < 3.45	0.541	0.541	ND < 3.95	ND < 0.198	ND < 3.95	ND < 3.67	ND < 0.184	ND < 3.67
Dibenz(a,h)anthracene	ND < 3.45	0.719	0.719	ND < 3.95	0.320	0.320	ND < 3.67	0.299	0.299
Benzo(g,h,i)perylene	ND < 3.45	0.553	0.553	ND < 3.95	0.208	0.208	ND < 3.67	ND < 0.184	ND < 3.67

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

Sample results corrected for train blank.

TABLE 7.1-9. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC FROM BAGHOUSE OUTLET (LOCATION 19) (ng/Nm³)

Analyte	N-19-MM5- X-718	N-19-MM5- F-718	N-19-MM5- F+X-718	N-19-MM5- X-721	N-19-MM5- F-721	N-19-MM5- F+X-721	N-19-MM5- X-723	N-19-MM5- F-723	N-19-MM5- F+X-723
Benzylchloride	ND < 8.83	ND < 0.883	ND < 8.83	ND < 18.9	ND < 0.945	ND < 18.9	ND < 9.49	1.38	1.38
Acetophenone	68.6	30.3	98.9	179	ND < 0.945	179	371	ND < 0.949	371
Hexachloroethane	ND < 8.83	ND < 0.883	ND < 8.83	ND < 18.9	ND < 0.945	ND < 18.9	ND < 9.49	ND < 0.949	ND < 9.49
Naphthalene	14.9	118	133	116	4.17	120	ND < 1.90	1.42	1.42
Hexachlorobutadiene	ND < 8.83	ND < 0.883	ND < 8.83	ND < 18.9	ND < 0.945	ND < 18.9	ND < 9.49	ND < 0.949	ND < 9.49
2-Chloroacetophenone	ND < 8.83	1290	1290	ND < 18.9	25.3	25.3	ND < 9.49	ND < 0.949	ND < 9.49
2-Methylnaphthalene	26.7	31.0	57.7	18.2	1.75	20.0	ND < 9.49	ND < 0.949	ND < 9.49
1-Methylnaphthalene	12.2	17.9	30.1	8.49	2.92	11.4	19.5	1.57	21.1
Hexachlorocyclopentadiene	ND < 8.83	ND < 0.883	ND < 8.83	ND < 18.9	ND < 0.945	ND < 18.9	ND < 9.49	ND < 0.949	ND < 9.49
Biphenyl	47.8	2670 E	2710 E	135	388 E	523 E	88.4	0.300	88.7
Acenaphthylene	22.4	7.73	30.1	18.3	1.51	19.8	2.11	0.308	2.41
2,6-Dinitrotoluene	ND < 8.83	ND < 0.883	ND < 8.83	ND < 18.9	ND < 0.945	ND < 18.9	ND < 9.49	ND < 0.949	ND < 9.49
Acenaphthene	36.9	683	719	37.8	1.12	38.9	6.87	0.226	7.10
Dibenzofuran	77.6	130	208	252	6.37	258	62.9	2.03	64.9
2,4-Dinitrotoluene	10.3	ND < 0.883	10.3	43.0	ND < 0.945	43.0	10.3	ND < 0.949	10.3
Fluorene	7.26	59.3	66.6	53.1	1.86	55.0	5.06	0.325	5.38
Hexachlorobenzene	ND < 8.83	ND < 0.883	ND < 8.83	ND < 18.9	ND < 0.945	ND < 18.9	ND < 9.49	ND < 0.949	ND < 9.49
Pentachlorophenol	ND < 8.83	ND < 0.883	ND < 8.83	ND < 18.9	ND < 0.945	ND < 18.9	ND < 9.49	ND < 0.949	ND < 9.49
Phenanthrene	47.2	39.7	86.9	148	3.63	152	58.4	2.94	61.3
Anthracene	2.39	4.15	6.54	5.96	0.557	6.51	2.91	0.614	3.52
Fluoranthene	5.02	10.8	15.8	11.3	6.02	17.3	12.9	3.44	16.4
Pyrene	ND < 1.77	1.03	1.03	ND < 3.78	1.49	1.49	ND < 1.90	2.18	2.18
Benz(a)anthracene	3.72	ND < 0.177	3.72	11.8	1.07	12.9	ND < 1.90	1.86	1.86
Chrysene	2.87	ND < 0.177	2.87	5.94	4.58	10.5	8.19	3.77	12.0
Benzo(b & k)fluoranthene	ND < 1.77	ND < 0.177	ND < 1.77	5.35	3.03	8.38	ND < 1.90	5.07	5.07
Benzo(e)pyrene	ND < 1.77	ND < 0.177	ND < 1.77	ND < 3.78	1.24	1.24	ND < 1.90	1.52	1.52
Benzo(a)pyrene	ND < 1.77	ND < 0.177	ND < 1.77	ND < 3.78	2.65	2.65	ND < 1.90	0.870	0.870
Indeno(1,2,3-c,d)pyrene	ND < 1.77	3.14	3.14	ND < 3.78	1.91	1.91	ND < 1.90	0.954	0.954
Dibenz(a,h)anthracene	ND < 1.77	ND < 0.177	ND < 1.77	ND < 3.78	0.514	0.514	ND < 1.90	0.758	0.758
Benzo(g,h,i)perylene	ND < 1.77	ND < 0.177	ND < 1.77	ND < 3.78	0.767	0.767	ND < 1.90	0.843	0.843

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

Sample results corrected for train blank.

TABLE 7.i-10. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC FROM SCR REACTOR OUTLET (LOCATION 20) (ug/Nm³)

Analyte	N-20-MM5 X-718	N-20-MM5- F-718	N-20-MM5- F+X-718	N-20-MM5- X-721	N-20-MM5- F-721	N-20-MM5- F+X-721	N-20-MM5- X-723	N-20-MM5- F-723	N-20-MM5- F+X-723
(a)									
Benzylchloride	ND < 1.13	ND < 1.13	ND < 1.13	ND < 25.4	ND < 1.27	ND < 25.4	ND < 25.4	ND < 1.27	ND < 25.4
Acetophenone	ND < 1.13	ND < 1.13	ND < 1.13	407	5.15	412	474	ND < 1.27	474
Hexachloroethane	ND < 1.13	ND < 1.13	ND < 1.13	20.9	28.4	49.2	75.4	ND < 1.27	ND < 25.4
Naphthalene	4.00	4.00	4.00	ND < 25.4	ND < 1.27	ND < 25.4	ND < 25.4	1.56	76.9
Hexachlorobutadiene	ND < 1.13	ND < 1.13	ND < 1.13	ND < 25.4	43.1	43.1	ND < 25.4	ND < 1.27	ND < 25.4
2-Chloroacetophenone	ND < 1.13	ND < 1.13	ND < 1.13	ND < 25.4	13.2	32.1	ND < 25.4	ND < 1.27	ND < 25.4
2-Methylnaphthalene	2.89	2.89	2.89	18.8	5.95	17.5	18.6	0.75	19.3
1-Methylnaphthalene	2.89	2.89	2.89	11.6	5.95	17.5	12.5	ND < 0.25	12.5
Hexachlorocyclopentadiene	ND < 1.13	ND < 1.13	ND < 1.13	ND < 25.4	ND < 1.27	ND < 25.4	ND < 25.4	ND < 1.27	ND < 25.4
Biphenyl	248 E	248 E	248 E	260	1050 E	1310 E	6.11	83.1 E	89.3 E
Acenaphthylene	ND < 0.226	ND < 0.226	ND < 0.226	ND < 5.09	0.574	0.574	ND < 5.09	ND < 0.25	ND < 5.09
2,6-Dinitrotoluene	66.9	66.9	66.9	ND < 25.4	ND < 1.27	ND < 25.4	ND < 25.4	ND < 1.27	ND < 25.4
Acenaphthene	ND < 0.226	ND < 0.226	ND < 0.226	10.2	6.45	16.6	11.4	ND < 0.25	11.4
Dibenzofuran	7.25	7.25	7.25	43.1	16.4	59.6	ND < 25.4	2.79	2.79
2,4-Dinitrotoluene	1.84	1.84	1.84	ND < 25.4	54.5	54.5	ND < 25.4	ND < 1.27	ND < 25.4
Fluorene	2.11	2.11	2.11	ND < 5.09	11.9	11.9	ND < 5.09	ND < 0.254	ND < 5.09
Hexachlorobenzene	ND < 1.13	ND < 1.13	ND < 1.13	ND < 25.4	ND < 1.27	ND < 25.4	ND < 25.4	ND < 1.27	ND < 25.4
Pentachlorophenol	ND < 1.13	ND < 1.13	ND < 1.13	ND < 25.4	ND < 1.27	ND < 25.4	ND < 25.4	ND < 1.27	ND < 25.4
Phenanthrene	ND < 0.226	ND < 0.226	ND < 0.226	67.9	17.6	85.4	ND < 25.4	ND < 1.27	ND < 25.4
Anthracene	0.588	0.588	0.588	6.72	0.742	7.46	51.8	ND < 0.254	51.8
Fluoranthene	ND < 0.226	ND < 0.226	ND < 0.226	26.3	ND < 0.254	26.3	ND < 5.09	0.411	0.411
Pyrene	1.03	1.03	1.03	5.90	ND < 0.254	5.90	ND < 5.09	2.62	21.0
Benz(a)anthracene	ND < 0.226	ND < 0.226	ND < 0.226	ND < 5.09	ND < 0.254	ND < 5.09	ND < 5.09	0.365	0.365
Chrysene	3.14	3.14	3.14	17.0	ND < 0.254	17.0	7.80	0.505	0.505
Benzo(b & k)fluoranthene	9.96	9.96	9.96	8.38	22.6	31.0	5.95	0.430	8.23
Benzo(e)pyrene	2.79	2.79	2.79	ND < 5.09	10.6	10.6	ND < 5.09	1.64	7.59
Benzo(a)pyrene	0.628	0.628	0.628	ND < 5.09	ND < 0.254	ND < 5.09	ND < 5.09	0.651	0.651
Indeno(1,2,3-c,d)pyrene	1.51	1.51	1.51	ND < 5.09	ND < 0.254	ND < 5.09	ND < 5.09	0.260	0.260
Dibenz(a,h)anthracene	3.31	3.31	3.31	ND < 5.09	ND < 0.254	ND < 5.09	ND < 5.09	0.627	9.28
Benzo(g,h,i)perylene	2.64	2.64	2.64	ND < 5.09	ND < 0.254	ND < 5.09	ND < 5.09	0.503	0.503
								0.514	0.514

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

Sample results corrected for train blank.

(a) Sample was lost during sample preparation process.

TABLE 7.1-11. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC FROM WSA CONDENSER OUTLET (LOCATION 21) (ug/Nm³)

Analyte	N-21-MM5- X-718	N-21-MM5- F-718	N-21-MM5- F+X-718	N-21-MM5- X-721	N-21-MM5- F-721	N-21-MM5- F+X-721	N-21-MM5- X-723	N-21-MM5- F-723	N-21-MM5- F+X-723
Benzylchloride	1.92	ND < 1.04	1.92	ND < 11.5	ND < 1.15	90.9	ND < 9.97	1.72	1.72
Acetophenone	145 E	ND < 1.04	145 E	472	ND < 1.15	472	627	ND < 1.00	627
Hexachloroethane	ND < 1.04	ND < 1.04	ND < 1.04	ND < 11.5	ND < 1.15	ND < 11.5	ND < 9.97	ND < 1.00	ND < 9.97
Naphthalene	84.8 E	0.58	85.3 E	111	2.22	113	45.8	1.56	47.4
Hexachlorobutadiene	ND < 1.04	ND < 1.04	ND < 1.04	ND < 11.5	ND < 1.15	ND < 11.5	ND < 9.97	ND < 1.00	ND < 9.97
2-Chloroacetophenone	ND < 1.04	ND < 1.04	ND < 1.04	ND < 11.5	3.21	3.21	ND < 9.97	ND < 1.00	ND < 9.97
2-Methylnaphthalene	13.7	0.63	14.4	54.1	1.15	55.2	11.3	1.01	12.3
1-Methylnaphthalene	8.04	ND < 0.21	8.04	30.1	0.529	30.6	7.94	0.383	8.32
Hexachlorocyclopentadiene	ND < 1.04	ND < 1.04	ND < 1.04	ND < 11.5	ND < 1.15	ND < 11.5	ND < 9.97	ND < 1.00	ND < 9.97
Biphenyl	ND < 0.207	19.5	19.5	2.92	1.01	3.94	ND < 1.99	0.424	0.42
Acenaphthylene	2.79	ND < 0.207	2.79	10.3	0.268	10.6	3.53	ND < 0.199	3.53
2,6-Dinitrotoluene	ND < 1.04	ND < 1.04	ND < 1.04	ND < 11.5	ND < 1.15	ND < 11.5	ND < 9.97	ND < 1.00	ND < 9.97
Acenaphthene	7.49	ND < 0.207	7.49	11.4	ND < 0.230	11.4	2.82	ND < 0.199	2.82
Dibenzofuran	15.8	1.61	17.4	22.4	1.53	24.0	12.5	1.29	13.7
2,4-Dinitrotoluene	3.75	1.23	4.98	ND < 11.5	ND < 1.15	ND < 11.5	ND < 9.97	ND < 1.00	ND < 9.97
Fluorene	ND < 0.207	0.229	0.229	ND < 2.30	ND < 0.230	ND < 2.30	ND < 1.99	ND < 0.199	ND < 1.99
Hexachlorobenzene	ND < 1.04	ND < 1.04	ND < 1.04	ND < 11.5	ND < 1.15	ND < 11.5	ND < 9.97	ND < 1.00	ND < 9.97
Pentachlorophenol	ND < 1.04	1.92	1.92	ND < 11.5	ND < 1.15	ND < 11.5	ND < 9.97	ND < 1.00	ND < 9.97
Phenanthrene	50.2 E	ND < 0.207	50.2 E	25.3	2.30	27.6	21.6	ND < 0.199	21.6
Anthracene	1.82	0.289	2.11	5.45	2.25	7.70	4.64	0.300	4.94
Fluoranthene	11.8	1.73	13.5	7.28	1.22	8.51	5.15	1.13	6.28
Pyrene	ND < 0.207	0.505	0.505	ND < 2.30	2.24	2.24	ND < 1.99	0.273	0.273
Benz(a)anthracene	2.36	0.412	2.77	ND < 2.30	1.62	1.62	3.02	0.268	3.29
Chrysene	3.89	0.442	4.33	ND < 2.30	0.976	0.98	3.21	ND < 0.199	3.21
Benzo(b & k)fluoranthene	5.06	1.55	6.60	ND < 2.30	3.19	3.19	4.53	0.612	5.14
Benzo(e)pyrene	1.87	0.618	2.49	ND < 2.30	0.870	0.870	ND < 1.99	0.260	0.260
Benzo(a)pyrene	1.62	ND < 0.207	1.62	ND < 2.30	ND < 0.230	ND < 2.30	ND < 1.99	ND < 0.199	ND < 1.99
Indeno(1,2,3-c,d)pyrene	1.64	0.398	2.04	ND < 2.30	0.661	0.661	ND < 1.99	ND < 0.199	ND < 1.99
Dibenz(a,h)anthracene	0.660	ND < 0.207	0.660	ND < 2.30	1.02	1.02	ND < 1.99	ND < 0.199	ND < 1.99
Benzo(g,h,i)perylene	1.59	ND < 0.207	1.59	ND < 2.30	0.952	0.952	ND < 1.99	ND < 0.199	ND < 1.99

ND < = Not detected, value following ND < is detection limit.

E = Concentration detected above calibration range.

Sample results corrected for train blank.

TABLE 7.1-12. VAPOR/PARTICULATE DISTRIBUTION FOR PAH/SVOC IN BLANK GAS SAMPLES (ng/Nm³)

Analyte	N-21-MM5-		N-21-MM5-		TRAIN BLANK	
	X-717	F-717	X-717	F-717	N-21-MM5-	F+X-717
Benzylchloride	ND < 21.1	ND < 2.11	ND < 2.11	ND < 2.11	ND < 21.1	ND < 21.1
Acetophenone	116	11.2	11.2	11.2	127	127
Hexachloroethane	ND < 21.1	ND < 2.11	ND < 2.11	ND < 2.11	ND < 21.1	ND < 21.1
Naphthalene	176	1.14	1.14	1.14	178	178
Hexachlorobutadiene	ND < 21.1	ND < 2.11	ND < 2.11	ND < 2.11	ND < 21.1	ND < 21.1
2-Chloroacetophenone	1070	2.11	2.11	2.11	1070	1070
2-Methylnaphthalene	ND < 4.23	0.945	0.945	0.945	ND < 4.23	ND < 4.23
1-Methylnaphthalene	ND < 4.23	0.524	0.524	0.524	ND < 4.23	ND < 4.23
Hexachlorocyclopentadiene	ND < 21.1	ND < 2.11	ND < 2.11	ND < 2.11	ND < 21.1	ND < 21.1
Biphenyl	8.12	0.751	0.751	0.751	8.87	8.87
Acenaphthylene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23
2,6-Dinitrotoluene	1100	20.5	20.5	20.5	1120	1120
Acenaphthene	ND < 4.23	0.905	0.905	0.905	ND < 4.23	ND < 4.23
Dibenzofuran	ND < 21.1	ND < 2.11	ND < 2.11	ND < 2.11	ND < 21.1	ND < 21.1
2,4-Dinitrotoluene	ND < 21.1	ND < 2.11	ND < 2.11	ND < 2.11	ND < 21.1	ND < 21.1
Fluorene	16.4	1.64	1.64	1.64	18.1	18.1
Hexachlorobenzene	ND < 21.1	ND < 2.11	ND < 2.11	ND < 2.11	ND < 21.1	ND < 21.1
Pentachlorophenol	ND < 21.1	ND < 2.11	ND < 2.11	ND < 2.11	ND < 21.1	ND < 21.1
Phenanthrene	11.3	4.17	4.17	4.17	15.4	15.4
Anthracene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23
Fluoranthene	5.76	1.81	1.81	1.81	7.57	7.57
Pyrene	4.79	0.658	0.658	0.658	5.45	5.45
Benz(a)anthracene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23
Chrysene	ND < 4.23	0.571	0.571	0.571	ND < 4.23	ND < 4.23
Benzo(b & k)fluoranthene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23
Benzo(e)pyrene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23
Benzo(a)pyrene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23
Indeno(1,2,3-c,d)pyrene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23
Dibenz(a,h)anthracene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23
Benzo(g,h,i)perylene	ND < 4.23	ND < 0.423	ND < 0.423	ND < 0.423	ND < 4.23	ND < 4.23

ND < = Not detected, value following ND < is detection limit.
Sample results corrected for field reagent blank.

7.2 Particle Size Distribution of Elements in Flue Gas Streams

This section discusses the distribution of elemental concentrations among the various particle size fractions collected at Location 18. Three samples were collected at Location 18 (baghouse inlet) using a Multi-Metals sampling train. Various particle size fractions were collected separately in the train, using glass cyclones in the heated filter box upstream of the particle filter. The large cyclone had collection characteristics such that the $> 10\ \mu\text{m}$ aerodynamic size particles were collected in it, the small cyclone collected particles in the 5-10 μm aerodynamic size range, and the downstream quartz filter collected the $< 5\ \mu\text{m}$ size fraction. The cyclone cutpoints were based on a computer program used to design the cyclones prior to the study. Insufficient time was available before the field study to conduct confirmatory tests of the cyclone cutpoints.

The sampling constraints of Location 18 necessitated the use of a heated flexible Teflon line, of smooth inner bore and about 8 feet long, to connect the sampling probe to the inlet of the large cyclone. The particulate fraction collected in this tubing, together with that in the sampling probe, were collectively analyzed and are referred to here as the probe rinse particulate fraction. Due to the length of the tubing and complexity of the flow path, the particle size range collected as the probe rinse fraction is difficult to estimate. For this reason this collection material is excluded from some of the subsequent discussion. However, it is expected from aerosol dynamics that, on a mass basis, larger particles would be preferentially removed in the probe and tubing compared with smaller particles. Note that on average at Location 18, 48.7 percent of the collected particulate matter was found in the probe rinse, 15.4 percent in the large ($> 10\ \mu\text{m}$) cyclone, 18.1 percent in the small (5-10 μm) cyclone, and 17.8 percent on the filter (Section 5.10).

The various particle fractions collected in the three samples at Location 18 were analyzed for elemental concentrations. Table 7.2-1 provides the measured particle-phase elemental concentrations of various elements in each of the three known size fractions.

7.2.1 Average Distribution of Elemental Concentrations

A more informative picture of the particle size distribution of elemental pollutants in the flue gas is provided in Table 7.2-2. This table provides the average percentage distributions of elemental flue gas concentrations among the various size fractions at Location 18. The data in Table 7.2-2 have been derived by averaging the elemental concentrations measured in the respective particle size fractions in each of the three samples collected at this sampling location; zero values were used for elemental concentrations in size fractions that were below the detection limit in any sample. Each entry in the tables is the average percentage of the total flue gas loading of the indicated elements, that is contributed by the indicated size fraction of particles. The sum of the percentages across the row for each element equals 100 percent. For example, in Table 7.2-2, aluminum in flue gas at Location 18 exists about 15.1 percent in $<5\ \mu\text{m}$ particles, 9.6 percent in $5\text{-}10\ \mu\text{m}$ particles, 7.6 percent in $10\ \mu\text{m}$ particles, and 67.7 percent in particles collected in the probe and flexible tubing. Table 7.2-2 thus provides a perspective on the distribution of individual elements among the various particle fractions in the flue gas stream upstream of the baghouse.

Table 7.2-2 shows that at Location 18 the probe rinse particle fraction contained the largest proportion of the elemental concentrations for nearly all of the elements. The second-largest elemental fractions in nearly all cases were in the filter or $<5\ \mu\text{m}$ size range, followed by the small cyclone and the large cyclone fractions. The large and small cyclone fractions had generally similar proportions of elemental concentrations for all elements.

A few elements, including antimony, arsenic, cadmium, chromium, molybdenum, and sodium, had $>30\%$ of their particulate phase concentrations in the filter or $<5\ \mu\text{m}$ fraction. The remainder of the elements had typically between 15-30% of their particulate phase concentrations in the filter fraction. The elemental concentration in the large and small cyclone fractions were almost always less than the corresponding concentrations in the filter fraction. Typically, the two cyclone fractions combined were equal to or less than the corresponding elemental fraction in the filter.

No individual trends in the particle elemental distributions could be observed for any of the elements, either with increasing or decreasing particle size. In summary, the elemental concentrations contained in the probe rinse and filter fractions typically made up

60-80% of the total particulate phase concentrations for most elements, with the two cyclone fractions being similar to each other, and smaller than the corresponding filter fraction.

7.2.2 Elemental Content Ratios

The elemental concentrations in Table 7.2-1 can also be interpreted in terms of the fraction of particle mass in each of the various particle fractions that is made up of individual elements. Table 7.2-3 shows the average elemental content for the four particle size collection fractions and the total particulate matter at Location 18. The distribution of particle mass was presented in Table 5-56. The data in Tables 7.2-3 have been derived by averaging the elemental concentration data (in $\mu\text{g}/\text{Nm}^3$) in the three samples at location 18 (Tables 7.2), multiplying the average concentrations by the average sample volume (in Nm^3), and dividing by the average particle mass (in g) collected of each size fraction. Zero values were used for elemental concentrations in size fractions that were below the detection limit in any sample. Thus the entries in Tables 7.2-3 show the elemental composition (in $\mu\text{g}/\text{g}$) of each particle size fraction, as well as of the total particle mass.

Table 7.2-3 shows that at Location 18, many of the elements, such as barium, beryllium, cobalt, lead, manganese, nickel, potassium, and titanium, are relatively evenly present in all size fractions, including the probe rinse fraction. By contrast, aluminum is substantially enriched in the probe rinse fraction compared with the relatively uniform content in the other size fractions.

Only a few elements appear to have elemental contents that are clearly higher in the filter fraction compared with those in the other, larger size fractions. Most notable are selenium, arsenic, and antimony. Chromium, copper, molybdenum, and sodium has shown this trend. Nearly all of the elements have similar content ratios in the large and small cyclone fractions.

In general, the content ratios for the total particle mass are of the same order as the content ratios in the individual size fractions. This result is consistent with the observation made above that the major elements are evenly distributed in all the measured size fractions.

The collection of size-segregated particle samples at Location 18 suffered from the necessity to use an extractive approach to sampling, i.e., the use of a probe and sample line

followed by cyclone collectors rather than inserting cyclones directly into the flue gas. Large amounts of particulate material were deposited in the sampling line ahead of the particle collectors. The data on size dependence of elemental composition is of limited value.

What can be said is that the results are qualitatively consistent with the expectation that the more volatile elements would be concentrated in the smaller size fly ash particles. The elements selenium, arsenic, and antimony exhibit this trend and are in sharp contrast to aluminum which was concentrated in the larger particle size fractions. Figure 7.2-1 displays the relative elemental composition of samples from Location 18 across different components of the sampling train. For each element the data in Table 7.2-3 were normalized by dividing the reported concentration in $\mu\text{g/g}$ for each stage of the sampling train by the reported concentration for the filter (e.g., for selenium in the sample collected in the small cyclone, the value is $26/71 = 0.37$). If elements are concentrated in smaller particle size ranges, as is expected for selenium and antimony, the ratio of concentrations would be expected to be less with increasing particle size. For elements such as titanium and nickel, which are less volatile, the ratio of concentrations would be expected to be more uniform across the different stages of the sampling train. Some evidence of these effects can be seen in the data; however, the necessity of using a long sampling probe and hose prior to the cyclones had a negative impact on ascertaining the particle size dependence of elements.

TABLE 7.2-1. PARTICULATE SIZE DISTRIBUTION OF ELEMENTS IN BAGHOUSE INLET (LOCATION 18) ($\mu\text{g}/\text{Nm}^3$)

Analyte	N-18-MUM-719				N-18-MUM-722				N-18-MUM-724			
	SMALL		LARGE		SMALL		LARGE		SMALL		LARGE	
	CYCLONE	CYCLONE	FILTER	TOTAL	CYCLONE	CYCLONE	FILTER	TOTAL	CYCLONE	CYCLONE	FILTER	TOTAL
Aluminum	15402	3287	29052	54920	7903	15588	23727	55311	10605	31968	16342	62533
Potassium	10518	2160	10313	26449	1992	3317	9034	16825	2534	7461	6713	17734
Silicon	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sodium	1516	263	1926	4261	221	387	2355	3471	256	832	1991	3268
Titanium	4132	1202	3675	10365	786	1520	3042	6265	1011	3444	2397	7272
Antimony	14.8	5.63	62.5	95.4	3.43	4.15	43.1	59.4	5.27	10.3	40.6	59.6
Arsenic	1315	282	1551	3621	199	409	1178	2092	261	758	907	2043
Barium	82.6	33.8	403	598	56.4	99.5	349	592	86.8	224	308	656
Beryllium	22.5	6.39	28.2	65.7	4.21	6.91	21.3	38.00	5.12	15.5	16.5	39.4
Boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	5.82	ND <	0.188	12.1	ND <	0.221	ND <	4.29	ND <	1.15	1.08	1.15
Chromium	173	54.5	259	560	32.1	58.0	224	368	39.9	121	167	347
Cobalt	62.0	16.3	57.8	157	12.2	21.6	55.5	105	15.7	45.3	43.3	111
Copper	263	65.7	291	712	42.1	69.1	257	431	49.8	172	181	427
Lead	244	97.7	442	902	57.6	88.4	183	385	92.5	189	134	441
Manganese	301	37.6	158	571	32.1	60.8	146	280	39.9	126	90.3	272
Molybdenum	71.4	22.5	267	415	16.6	19.1	201	278	19.9	51.1	129	212
Nickel	193	50.7	198	508	37.6	63.6	181	331	52.7	155	147	376
Selenium	41.3	5.45	30.6	89.0	1.77	7.19	29.1	44.5	2.42	10.3	23.6	38.6
Vanadium	263	73.3	346	785	47.6	80.2	297	498	56.9	189	227	503

ND < = Not detected, value following ND < is detection limit.

NA = Sample not available, sample not analyzed, or data not available.

TABLE 7.2-2. AVERAGE DISTRIBUTION OF ELEMENTS IN PARTICULATE MATTER COLLECTED
IN THE FOUR PARTS OF THE SAMPLING TRAIN AT LOCATION 18

SPECIES	Percentage Elemental Distribution							
	Filter		Small Cyclone		Large Cyclone		Probe Rinse	
	%	±SD%	< 5 µm	5 - 10 µm	> 10 µm	Unknown size	%	±SD%
Elements								
Aluminum	15.1	7.7	9.6	7.7	7.6	4.5	67.7	7.3
Antimony	51.2	7.3	7.2	3.7	8	5.4	33.6	10.9
Arsenic	36.7	4.9	15.6	9.5	16.5	15.1	31.2	11.3
Barium	27.6	10.1	8.2	5.9	5.8	2.1	58.3	8.3
Beryllium	28	5.8	12.6	7.6	13.2	12	46.3	13.6
Cadmium	41.2	10.4	14.3	16.6	20.5	25.8	24	14.7
Chromium	35.4	5.5	13.1	7.2	13	12	38.4	12.6
Cobalt	25.5	4.2	13.5	7.5	15	14.4	46.1	14.2
Copper	27.3	5	11.9	7.9	13.2	13.6	47.6	14.3
Lead	26.9	12.6	14.5	7.7	13.8	7.9	44.8	15.8
Manganese	22.1	4	13.5	9.8	19.5	22.4	44.9	17.8
Molybdenum	71.6	9.8	12.7	10.1	11.8	8.6	3.8	1.1
Nickel	26.1	5	13.1	7.8	14.4	13.6	46.4	14.2
Potassium	19.4	5.6	9.4	6	11.8	12.3	59.4	14.7
Selenium	26.9	4.2	8.3	3.7	13.1	18.6	49.7	12.5
Silicon	-	-	-	-	-	-	-	-
Sodium	38.1	7.2	8.4	3.6	13.5	16.6	39.9	17.6
Titanium	20.5	4.8	13.8	8.1	13.5	13.2	52.2	14
Vanadium	24.5	17	6.9	2.3	11.4	14.4	57.1	30.9

∴ Particulate data not available for silicon

TABLE 7.2-3. AVERAGE CONTENT OF INDIVIDUAL ELEMENTS IN PARTICULATE MATTER COLLECTED IN THE FOUR PARTS OF THE SAMPLING TRAIN AND IN THE TOTAL PARTICULATE AT LOCATION 18

SPECIES	Elemental Content									
	Filter ≤ 5 μm		Small Cyclone 5 - 10 μm		Large Cyclone > 10 μm		Probe Rinse Unknown size		Total Particulate	
	μg/g	±SD	μg/g	±SD	μg/g	±SD	μg/g	±SD	μg/g	±SD
Elements										
Aluminum	58096	16010	54063	32716	43794	21231	105333	2619	74848	17729
Antimony	125	34	28	11	22	10	29	2	43	4
Arsenic	3109	871	1675	243	1484	168	936	74	1490	234
Barium	907	135	403	277	316	103	746	39	614	128
Beryllium	56	16	33	6	30	7	34	3	36	3
Cadmium	8	5	3	2	2	1	1	1	3	2
Chromium	555	121	251	59	247	63	217	6	277	21
Cobalt	134	19	95	26	84	10	89	5	94	6
Copper	621	143	336	52	312	69	394	25	402	32
Lead	653	445	476	199	408	143	367	40	407	71
Manganese	336	89	298	20	220	0	240	19	269	35
Molybdenum	510	181	122	40	97	32	10	3	126	38
Nickel	448	66	305	66	286	34	293	16	307	16
Potassium	22257	4673	15655	3690	12557	510	25625	1366	20809	2659
Selenium	71	9	26	16	25	7	46	11	44	9
Silicon	-	-	-	-	-	-	-	-	-	-
Sodium	5341	286	1803	186	1464	72	2106	936	2546	441
Titanium	7789	1703	6195	1567	6184	792	7347	251	6787	346
Vanadium	743	155	370	60	350	72	1391	1763	943	664

-. Particulate data not available for silicon

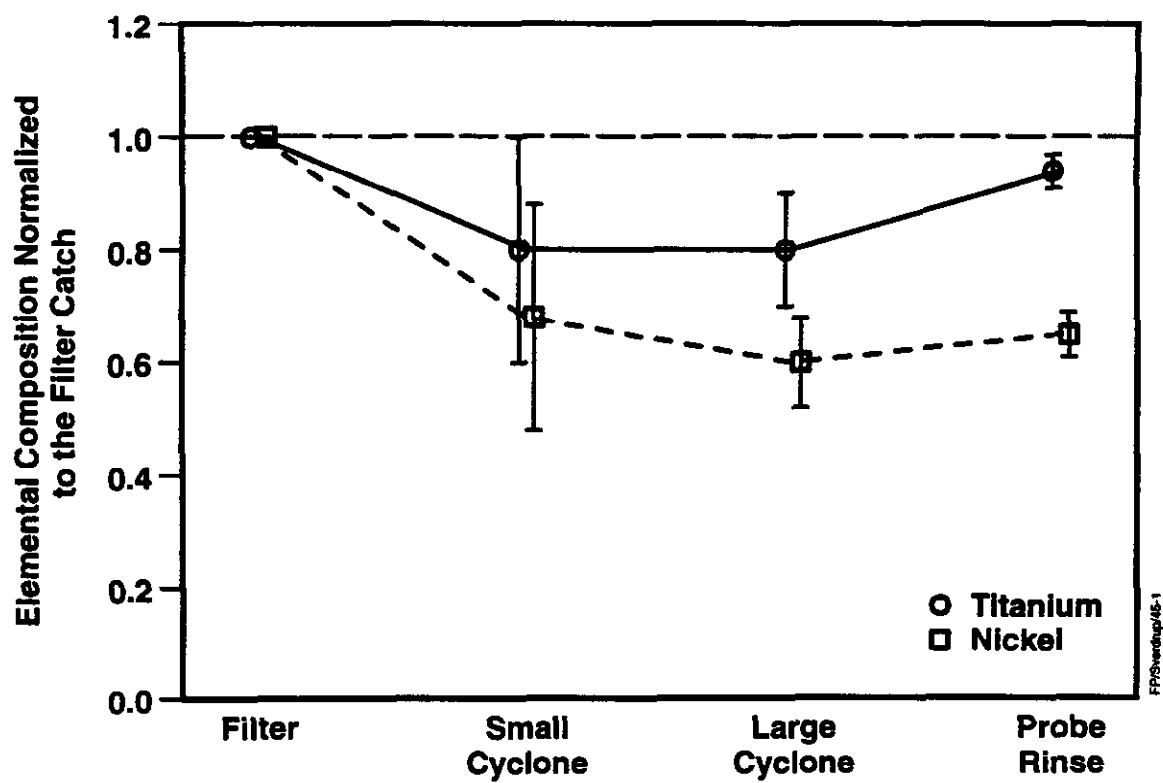
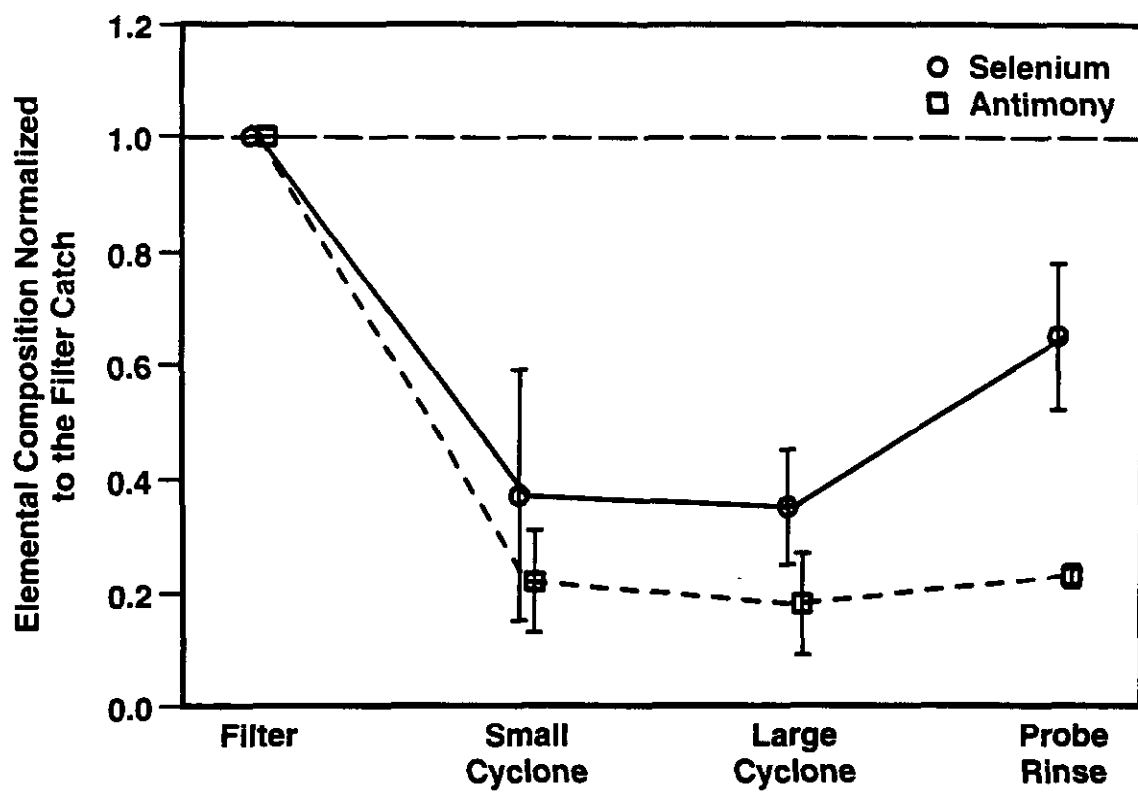


Figure 7.2-1. Relative elemental concentration in particulate matter across sampling train components

7.3 Comparison of HEST and Method 29 Methods for Volatile Elements

7.3.1 Introduction

Volatile trace elements (Hg, Se, As) were measured at four locations in the SNOX process using both Chester Environmental's Hazardous Element Sampling Train (HEST) and EPA's Draft Method 29 (Method 29). The objective was to provide two independent measurements for these elements as well as provide data to evaluate the HEST.

7.3.2 Experimental

Method 29: The Method 29 sampling train is illustrated in Figure 7.3-1. This sampling train was modified to collect size fractionated particle samples for multimetals analysis by adding a multistage-Pyrex impactor inside the heated box preceding the heated filter. The vapor phase samples were trapped in the impinger downstream of the quartz fiber particle filter. The Method 29 vapor phase results are based on the analysis of the impinger solution and the rinse solution of all glass surfaces downstream of the particulate quartz fiber filter including the filter support disks.

Particles were separated from the flue gas with cyclones and a quartz fiber filter. Method 29 requires that filtration take place in a box heated to 393 K ($248 \pm 25^\circ\text{F}$) to prevent condensation of moisture. The temperature of the air inside the box, however, is not necessarily the temperature of the flue or stack gas at the time of filtration. Flue or stack samples that are substantially higher than 393 K (248°F), for example, may not reach this recommended temperature prior to filtration. This may represent a particular problem with vapor phase Se species that can have a dew point in this same temperature range. Even if the stack gas temperatures approach the method specific temperature range, the particle and vapor phase ratio may not be representative of in situ conditions, if, the species dew point is likely to be near this temperature range.

The Method 29 samples were used to determine both the particle and gas phase concentration of elements. As such, collection of Method 29 samples included an isokinetic traverse of the stack or flue.

HEST Method: The HEST is illustrated in Figure 7.3-2. Two versions of this sampling train were used. One version, referred to as the low ash HEST (LAH), was as illustrated in Figure 7.3-2 with a quartz fiber filter followed by two carbon impregnated filters (CIF) all of which were housed in a Teflon-coated, stainless steel cartridge located at the end of the probe. In this LAH arrangement, the suspended particles were filtered at flue or stack gas temperatures. As such, particle and vapor phases were separated at in situ temperatures that accurately represent the process conditions.

The other HEST arrangement, referred to as the high ash HEST (HAH) was similar to the front half of the modified Method 29 with the particle phase being separated from the vapor phase with glass cyclones and a quartz fiber filter located outside the stack in a box heated to $248 \pm 24^{\circ}\text{F}$. The vapor phase elements were trapped on CIFs much like the LAH. The portion of the HAH downstream of the CIFs was similar to the back half of the LAH.

Only single point HEST samples were collected because only the vapor phase was determined by this method.

Sampling: Method 29 and HEST samples were collected from two different ports. The duration and flow rate of the HEST samples was generally less than that of Method 29 samples. The HEST sampling period typically overlapped about 40 to 50% of the Method 29 sampling period but at times was as low as about 30%.

The sampling conditions are summarized in Table 7.3-1.

7.3.3 Results

The HEST and Method 29 results are summarized in Tables 7.3-2 and 7.3-4. Selected particulate phase HEST results are presented to provide an estimate of the total concentration for comparison with the Method 29 total values. The HEST particle fraction represents only what was captured on the quartz fiber filter. This will be low by the amount of particulate fraction removed in the probe and cyclone in the HAH case. Both the HAH and LAH particle fractions will also be in error by the degree to which the single point sample is not representative and the degree to which the sample was nonisokinetic. These

factors, however, should not influence the vapor phase concentrations. Vapor phase results from the HEST samples are shown in the two columns labelled Gas-P (for primary) and Gas-S (for secondary or backup). Selected backup CIF filters were analyzed to document the extent of breakthrough of the three elements. The total HEST results (i.e., vapor plus solid phases) are shown in the column labelled total, and they are the sum of the Part., Gas-P, and Gas-S data.

7.3.4 Discussion

7.3.4.1 Overview. The vapor phase Hg, Se and As concentrations are in relatively poor agreement. The HEST Hg results are generally lower than the Method 29 Hg results. The HEST Se and As concentrations measured by the HEST are several fold greater than those based on the Method 29 samples. The differences in the Hg results are due in part to poor trapping efficiencies under some of the stack gas conditions. Other differences, particularly in the case of Se, are thought to be due to differences in temperature at the time the particle and vapor phases were separated. Some portion of the differences in results is due to the fact that the samples were not collected under identical conditions (different probes, different points in the stack, and differences in isokinetics) and the sampling times did not overlap completely.

These results have helped to define the dynamic range of applicability of the HEST. This comparison also suggests that Method 29 is limited in its ability to correctly define the in situ particle to vapor phase ratios for species that are near their dew point.

The HEST, like all methods has a dynamic range of applicability. It is recommended that the conditions (e.g., temperature range, moisture and acidity ranges, and flow rates) in which the HEST is applicable be defined more precisely. It is also recommended that whenever in situ phase partitioning information is required, particle filtration should be done at the in situ temperature. In addition, to avoid artifacts from gas phase interaction with filtered particles, denuders should be used to separate key gas phase components prior to filtration.

7.3.4.2 Mercury. The Hg results are compared in Table 7.3-2. The HEST Hg results from the primary CIF are generally lower than the Method 29 results. This is due in part to breakthrough of the Hg vapor to the backup CIF. The difference in method results is greatly reduced when the backup CIF Hg concentration is included and corrections made for x-ray absorption. Very little Hg was associated with the particle fraction, and potential differences in phase partitioning would have little impact on these differences.

The low Hg trapping efficiency at the baghouse inlet and outlet (Locations 18 and 19) may be due to a high temperature while the low Hg trapping efficiency of the HEST at the catalytic reactor outlet (Location 20) may have been due to both high temperature as well as condensation of sulfuric acid. The filters from Location 20 appeared as though they had been exposed to a liquid and lost physical stability as might be expected after being exposed to sulfuric acid.

A similar problem was observed with the first HEST sample collected at the condenser outlet (Location 21). In this case, a LAH was used to collect an in-stack sample. After sampling, the filters appeared wet, and the cotton fiber based CIF fell apart when it was removed. The two subsequent samples were collected with HAH arrangements where the filters were maintained at about 250°F which prevented condensation of sulfuric acid. For these last two samples, the agreement with the Method 29 samples was good and the HEST results were greater than the Method 29 results.

Although HAH arrangements were used to collect all valid samples from the SNOX process, the temperature of the gas at the time of filtration would vary depending on the temperature of the gas being sampled, flow rates and the temperature of the hot box which can vary between 223°F and 273°F and still stay within the Method 29 operating range. The three locations where poor agreement with Method 29 Hg were obtained are sites where the stack gas is substantially greater than the target hot box temperature (400°F and 600°F). This suggests that particle filtration and CIF Hg adsorption took place at a higher temperature than the nominal 250°F temperature of the air inside the hot box. This might explain in part the low Hg adsorption efficiency as well as the differences in the vapor phase Se and As discussed in the next section.

The Method 29 results at Locations 18, 19, 20, and 21 account for nearly all of the mercury calculated to have been entering the SNOX system in the coal. The Method 29 data

accounted for 88, 92, 97, and 97 percent of the mercury entering the SNOX system at Locations 18-21, respectively.

7.3.4.3 Selenium. The vapor phase Se HEST results are generally more than ten fold greater than the Method 29 vapor phase Se. The Se trapping efficiency was greater than 99% with the primary CIF for the samples collected at the baghouse inlet and outlet. Even at the SCR outlet (Location 20) where the CIFs appear to have been wet with sulfuric acid, only a small amount of the Se (<7%) penetrated to the backup CIF.

The average total Se results (particle plus vapor) were in good agreement at the baghouse inlet (112 $\mu\text{g}/\text{Nm}^3$ for the HEST and 105 $\mu\text{g}/\text{Nm}^3$ for Method 29). In this particular case, the difference in vapor phase concentrations appear to be due to differences in phase partitioning. Although similar front half sampling trains were used, it is quite possible that particle filtration took place at different temperatures. Since the dominant vapor phase Se species has a dew point in the potential range of filtration, it is quite likely that temperature differences are responsible for differences in vapor phase Se concentrations at Locations 18, 19, and 20.

Another indication that the Method 29 Se vapor results do not correctly represent the in situ Se concentration is the very low baghouse particulate Se removal efficiency (24%) based on Method 29 particle concentrations at the inlet and outlet of the baghouse.

The low vapor phase Se concentration at the inlet to the baghouse relative to the outlet as determined by the HEST may be due in part to gas phase removal by the thick particle deposit on the filter.

7.3.4.4 Arsenic. The vapor phase As HEST results are, like the Se results, several fold greater than the vapor phase concentrations reported by Method 29. The As trapping efficiency of the primary CIF was also greater than 99% as it was for Se. Because such a large fraction of the As was in the particulate phase much of which may have been removed in the probe and cyclones, the total concentrations could not be compared.

The baghouse As data suggest that the Method 29 results are not representative of the in situ vapor phase As concentrations. This is based on the following points:

- The baghouse penetration efficiency for both particles and vapor were similar; i.e., 0.4% and 0.6% , respectively. It is highly unlikely that the penetration efficiencies would be similar. It is more likely that most of the vapor phase As would penetrate the baghouse while most of the particulate phase would be collected by the baghouse.
- The Method 29 total As at the outlet was very close to the vapor phase HEST concentration. This would be expected if most of the As downstream of the baghouse was in the vapor phase and the Method 29 partitioning of the As is incorrect.

Both methods show a significant reduction of the vapor phase As downstream of the baghouse. This may be due to volatilization of a small portion of the large amount of As particulate captured upstream of the vapor phase measurement. This would not have been the case with the Se because it is dominated by the vapor phase.

7.3.5 Conclusion

The vapor phase Hg results reported by Method 29 are more representative of the in situ conditions in the SNOX process stream than the HEST results. The HEST results are low because of reduced trapping efficiency of the primary CIF caused by condensation of sulfuric acid and/or lack of temperature control within a specified dynamic range which had not been previously defined.

The HEST vapor phase Se and As results may be more representative of the in situ conditions than the Method 29 results. The difference, which was at times more than a factor of ten, is thought to be due to differences in phase partitioning and its high sensitivity to temperature.

The problems noted above can have a significant impact on derived factors such as baghouse efficiency.

If it is important that accurate particulate and vapor phase partitioning be achieved, it is essential that phase separation be achieved at in situ temperatures. It is also important that potential artifacts such as vapor phase interaction with particulate deposits and potential volatilization of particle deposits be eliminated.

7.3.6 Recommendations

The HEST is an easy-to-use, low-cost sampling train that can provide accurate and reliable measurements of vapor phase Hg, As and Se when operated within its dynamic range of applicability. Because this method is less than two years old, its dynamic range of applicability has not been completely defined. Prior to these measurements, it had not exceeded its range of applicability. The HEST's trapping efficiency depends on variables such as temperature, flow rate, analyte and interferant concentrations, and sampling time. As such, it is recommended that the dynamic range of the HEST be defined. It is further recommended that HEST samples be collected well above the dew point of sulfuric acid but below 450 K (350°F), preferably at about 420 K (300°F).

If accurate phase partitioning is required, it is recommended that phase separation take place at accurately controlled in situ temperatures.

If accurate phase partitioning is required, it is recommended that denuder methods be used to separate key vapor phase species prior to particle collection and vapor phase species be measured downstream of the particle filter to estimate particulate volatilization.

TABLE 7.3-1. SAMPLING CONDITIONS

Location	Site	Date	Stack Temp. (deg. F)	Part. Conc. ^(a) (mg/Nm ³)	SO ₂ (ppm)	HEST ^(b) Config.	CIF Temp. (deg. F)	Moisture (%)	CIF Dia. (mm)	Flow (slpm/cm ²)	Sampling ^(c) Overlap (%)
Baghouse Inlet	N-18	7-19	not recorded	2213	2086	HAH	243	10.8	86	0.394	31
		7-22	395	2019	1936	HAH	270	9.21	86	0.406	39
		7-24	380	2265	2061	HAH	291	8.90	86	0.293	54
		Mean	388	2166	2028		268	9.6		0.364	41
		Std	8	130	66		20	0.8		0.051	10
Baghouse Outlet	N-19	7-19	382	3.0	2086	HAH	261	10.3	86	0.557	22
		7-22	384	6.0	1936	HAH	264	9.35	86	0.429	34
		7-24	382	40.7	2061	HAH	266	9.26	86	0.415	36
		Mean	383	16.6	2028		264	9.6		0.467	31
		Std	1	30.0	66		2	0.5		0.064	6
SCR Outlet	N-20	7-19	635	349	2000	HAH	250	10.1	102	0.312	23
		7-22	679	248	1900	HAH	250	8.93	102	0.371	31
		7-24	657	360	2000	HAH	250	8.66	102	0.308	33
		Mean	657	319	1967		250	9.2		0.330	29
		Std	18	62	47		0	0.6		0.029	4
WSA-2 Condenser	N-21	7-19	202	61	83	LAH	250	8.96	47	1.79	12
		7-22	200	32	67	HAH	250	8.15	102	0.329	32
		7-24	201	55	68	HAH	250	7.98	102	0.318	40
		Mean	201	49	73		250	8.36		0.81	28
		Std	1	15	7		0	0.43		0.69	12

(a) Determined by Method 29.

(b) HAH = high ash HEST; LAH = low ash HEST.

(c) Percentage of M29 run during which the HEST was in use.

TABLE 7.3-2. MERCURY RESULTS ($\mu\text{g}/\text{Nm}^3$)

Location	Stack Temp.	Site I.D.	Date	HEST				Method 29			
				Type	Part.	Gas-P	Gas-S	Total ^(a)	Part.	Gas	Total
Baghouse Inlet	not recorded	N-18	7-19	HAH	ND 0.0 ^(b)	19.8		19.8	2.19	32.4	34.6
	395		7-22	HAH	ND 0.0 ^(b)	11.8 ^(c)	0.26 ^(c)	12.1	1.18	25.4	26.6
	380		7-24	HAH	ND 0.0 ^(b)	17.7		17.7	1.65	20.0	21.6
	388		Mean		0.0	16.4		16.5	1.67	25.9	27.6
	8	Std		0.0	4.2		4.0	0.51	6.2	6.6	
Baghouse Outlet	382	N-19	7-19	HAH	ND <0.079	21.9 ^(c)	0.805 ^(c)	22.7	0.048	28.4	28.4
	384		7-22	HAH	ND <0.108	22.3		22.3	ND 0	25.8	25.8
	382		7-24	HAH	ND <0.116	22.0 ^(c)	7.53 ^(c)	29.5	ND 0	29.6	29.6
	383		Mean		ND <0.101	22.1		24.8	0.01	27.9	27.9
	1	Std		0.019	0.2		4.0	0.02	1.9	1.9	
SCR Outlet	635	N-20	7-19	HAH		27.7 ^(c)	6.83 ^(c)	34.6	1.82	34.0	35.8
	679		7-22	HAH		0.954 ^(c)	17.5 ^(c)	18.6	0.054	29.0	29.0
	657		7-24	HAH		9.34 ^(c)	24.0 ^(c)	33.4	0.061	27.5	27.5
	657		Mean			12.7	16.1	28.9	0.65	30.1	30.8
	18	Std				13.7	8.7	8.9	1.0	3.4	4.4
WSA-2 Condenser	202	N-21	7-19	LAH		not avail.		not avail.	0.859	35.3	36.2
	200		7-22	HAH		30.2		30.2	0.855	21.1	22.0
	201		7-24	HAH		32.9		32.9	3.4	27.1	30.5
	201		Mean			31.6		31.6	1.7	27.8	29.6
	1	Std							1.5	7.1	7.1

(a) A total is reported for whatever analyses were performed. HEST particulate and secondary carbon filters were analyzed selectively.

(b) The detection limits for location 18 mercury were high due to x-ray interference by germanium. "ND 0.0" is reported rather than a large non-detect so that the mercury total is not distorted.

(c) When breakthrough occurred, the results were adjusted for x-ray absorption.

TABLE 7.3-3. SELENIUM RESULTS ($\mu\text{g}/\text{Nm}^3$)

Location	Stack Temp.	Site I.D.	Date	HEST				Method 29			
				Type	Part.	Gas-P	Gas-S	Total ^(a)	Part.	Gas	Total
Baghouse	not recorded	N-18	7-19	HAH	12.3	112	ND < 0.13	124	120	1.88	122
Inlet	395		7-22	HAH	5.42	71.1	0.941 ^(b)	77.4	81.6	9.19	90.8
	380		7-24	HAH	8.73	126		134	86.8	14.3	101
Mean	388				8.8	103		112	96	8.5	105
SD	8				3.4	29		30	21	6.2	16
Baghouse	382	N-19	7-19	HAH	0.561	189	0.043 ^(b)	190	68.0	13.9	81.9
Outlet	384		7-22	HAH	0.444	177		177	90.4	7.39	97.8
	382		7-24	HAH	0.415	183	ND < 0.143	183	68.5	5.79	74.3
Mean	383				0.473	183		183	75.6	9.0	84.7
SD	1				0.077	6		7	13	4.3	12.0
SCR	635	N-20	7-19	HAH		277	0.316	227	45.8	7.08	52.9
Outlet	679		7-22	HAH		275 ^(b)	29.8 ^(b)	304	105	3.83	109
	657		7-24	HAH		202 ^(b)	13.7 ^(b)	215	92.8	3.46	96.3
Mean	657					235	14.6	249	81.2	4.79	86.1
SD	18					37	14.8	48	31.3	1.99	29.4
WSA-2	202	N-21	7-19	LAH		not avail.		not avail.	0.93		1.42
Condenser	200		7-22	HAH		ND < 0.128		ND < 0.128	ND < 0.75	ND < 0.46	0.61
	201		7-24	HAH		ND < 0.152		ND < 0.152	ND < 0.98	ND < 0.46	0.72
Mean	201					ND < 0.140		ND < 0.140	0.89	0.47	0.92
SD	1								0.12	0.01	0.44

(a) A total is reported for whatever analyses were performed. HEST particulate and secondary carbon filters were analyzed selectively.

(b) When breakthrough occurred, the results were adjusted for x-ray absorption.

(c) The M29 total equals the average non-detected amount.

TABLE 7.3-4. ARSENIC RESULTS ($\mu\text{g}/\text{Nm}^3$)

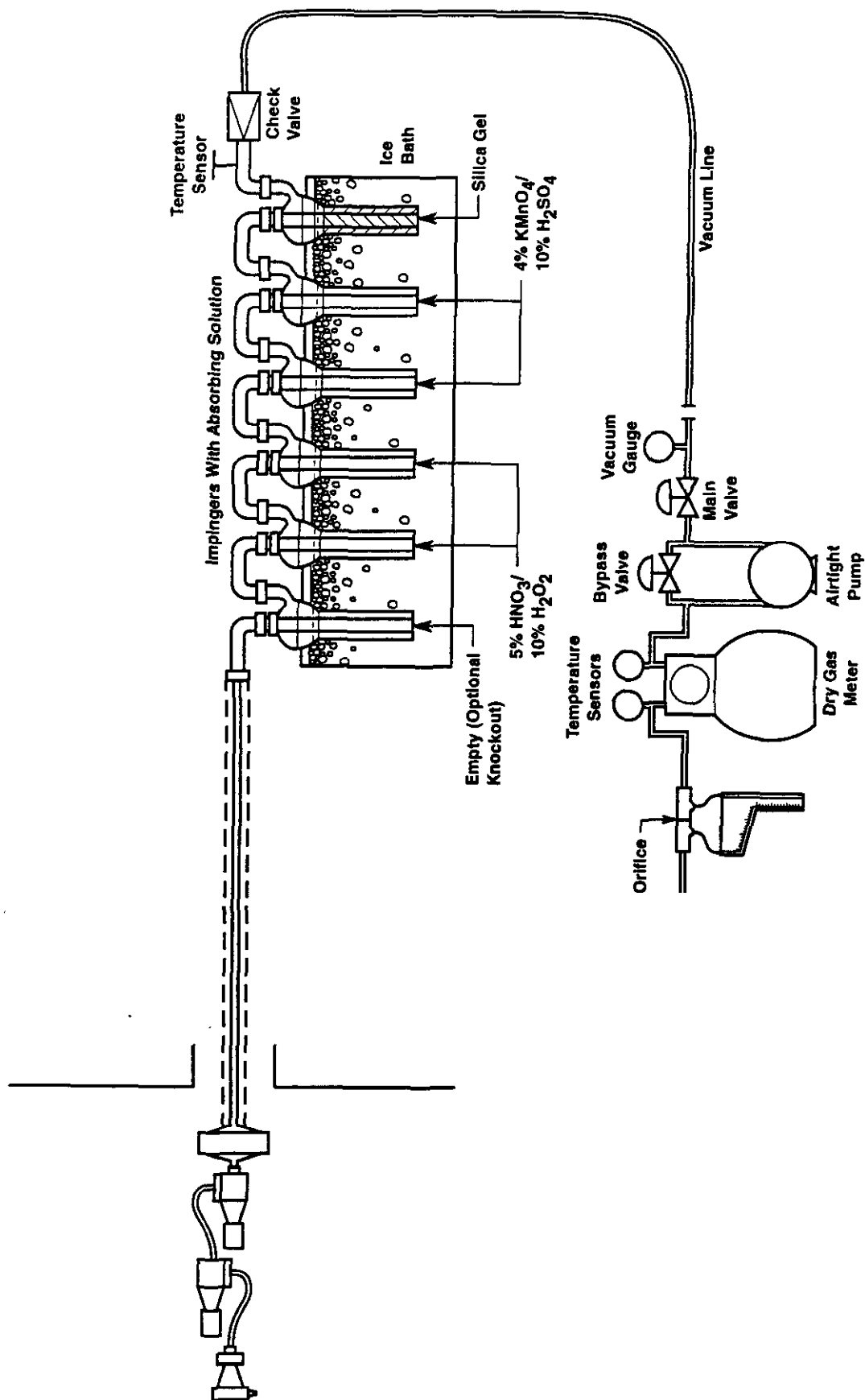
Location	Stack Temp.	Site I.D.	Date	HEST				Method 29			
				Type	Part.	Gas-P	Gas-S	Total ^(a)	Part.	Gas	Total
Baghouse Inlet	not recorded	N-18	7-19	HAH	1,040	128 ^(b)	0.663 ^(b)	1,170	3,880	85.8	3,960
	395		7-22	HAH	602	129 ^(b)	14.7 ^(b)	745	2,850	20.5	2,870
	380		7-24	HAH	899	128		1,030	2,950	23.8	2,980
	388				847	128		982	3,230	43.4	3,270
SD	8				224	0.6		217	568	36.8	600
Baghouse Outlet	382	N-19	7-19	HAH	4.38	18.1	ND < 0.169	22.4	17.1	0.52	17.6
	384		7-22	HAH	6.84	16.1		23.0	11.9	ND < 0.35	12.1
	382		7-24	HAH	4.05	8.59	ND < 0.237	12.7	9.04	ND < 0.36	9.23
	383				4.82	14.3		19.4	12.7	0.41	13.0
SD	1				1.36	5.0		5.8	4.1	0.10	4.3
SCR Outlet	635	N-20	7-19	HAH		ND < 0.138	ND < 0.406	ND < 0.544	4.63	ND < 0.65	4.95
	679		7-22	HAH		ND < 0.086	ND < 0.269	ND < 0.356	2.26	ND < 0.37	2.44
	657		7-24	HAH		ND < 0.110	ND < 0.324	ND <	ND < 1.26	ND < 0.41 ^(c)	ND < 0.55 ^(c)
	657					ND < 0.111	ND < 0.333	ND < 0.413	2.72	ND < 0.48	2.65
SD	18					0.026	0.069	0.115	1.73	0.15	2.21
WSA-2 Condenser	202	N-21	7-19	LAH		not avail.		not avail.	ND < 1.52 ^(c)	ND < 0.38 ^(c)	ND < 0.63 ^(c)
	200		7-22	HAH		ND < 0.10		ND < 0.010	ND < 1.57 ^(c)	ND < 0.46 ^(c)	ND < 0.68 ^(c)
	201		7-24	HAH		ND < 0.124		ND < 0.124	ND < 1.78 ^(c)	ND < 0.46 ^(c)	ND < 0.74 ^(c)
	201					ND < 0.11		ND < 0.11	ND < 1.62	ND < 0.43	ND < 0.68
SD	1					0.001			0.14	0.05	0.06

(a) A total is reported for whatever analyses were performed. HEST particulate and secondary carbon filters were analyzed selectively.

(b) When breakthrough occurred, the results were adjusted for x-ray absorption.

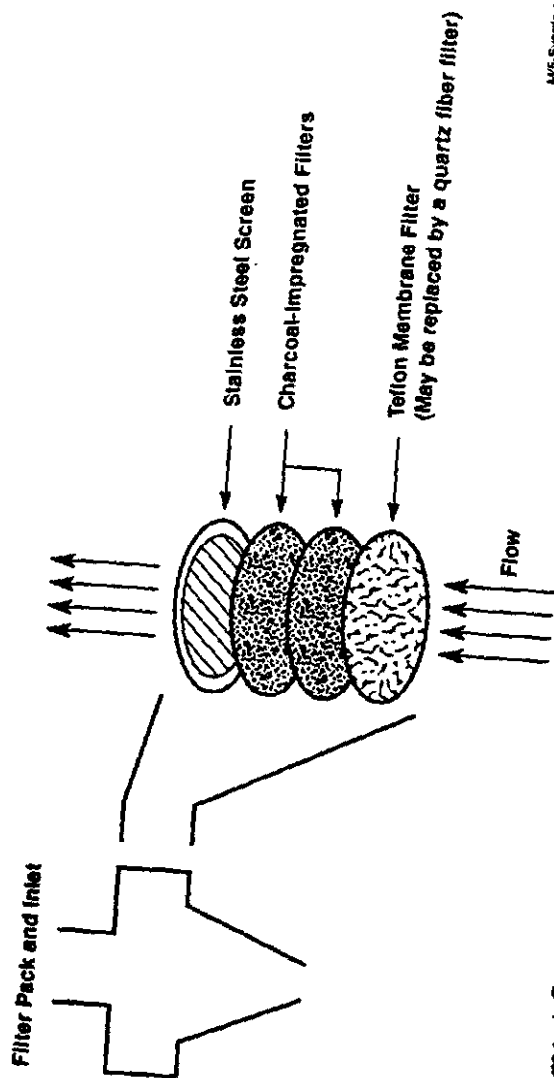
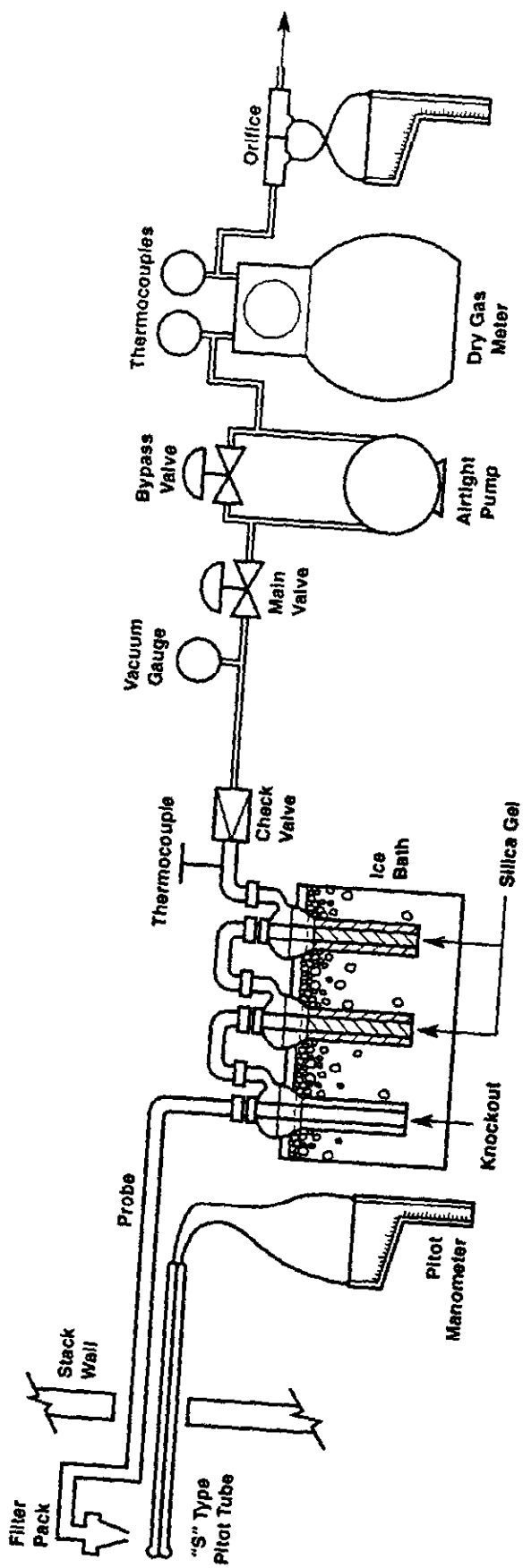
(c) When all M29 results for all analytical fractions are non-detects, the average is used for the total, rather than the sum of the fractions.

The particle phase result in this table equals the sum of the filter and front half rinse and cannot be averaged directly with the gas phase result to arrive at the total.



MS-Sw-044-2

Figure 7.3-1. Method 29 Train schematic



NI/5 Sverdrup/44-5

Figure 7.3-2. Hazardous Element Sampling Train

7.4 Comparison of VOST and Summa Canisters for VOC

The purpose of this special topic is to compare the analytical results from two established techniques that have been frequently used for collecting and analyzing volatile organic compounds (VOC) from various air matrices. The comparison is described in four parts: Sampling, Data Analysis, Conclusions, and Recommendations.

7.4.1 Sampling

The canister methodology made use of a flow orifice attached to the inlet of the evacuated canister. This permitted the collection of a time-integrated flue gas sample once the canister valve was opened. The VOST methodology made use of two adsorbent tubes, Tenax and Tenax/Charcoal, and a pump and flow controller assembly to sample the flue gas actively. Details on sampling and analysis with these methods are contained in the Sampling and Analysis Plans, and elsewhere in this report and are not repeated here.

The list of VOC to be measured using the canister methodology included the 41 components that are listed in U.S. EPA's TO-14 Methodology. The corresponding list for the VOST Methodology included 36 components and originates from SW-846, Method 5041 for VOC. Twenty compounds were common to both lists. The Method 5041 list contains 8 oxygenated species not on the TO-14 list. The TO-14 list includes several chlorinated and aromatic species not on the VOST list.

Samples were collected with both methods at the four flue gas locations during three organic test days. At each sampling location, three samples were collected sequentially with each method for each test run. For the VOST sampling, each set was comprised of a 5-minute, 10-minute and 30-minute sample at a nominal flow rate of 0.5 L/min. The sampling was carried out in that order, i.e. from short to long sampling times. This distributive volume approach was used to determine if breakthrough had occurred for any species and to extend the detection level for those species not exhibiting breakthrough. Canister sampling was initiated close to the start of each VOST collection time. However, the canisters were fitted with an orifice designed to fill the canister over a fixed time period of 30 minutes. As

a result, start and stop times for individual VOST and canister samples generally did not coincide.

Because of problems encountered during earlier power plant studies i.e. rapid deterioration of the analytical columns and poor analytical precision, a preliminary sampling effort was carried out at the Niles Station prior to the full scale study. Several canister samples were collected at the site and returned to Battelle for analysis. The preconcentration trap on the gas chromatograph/mass spectrometer had previously contained glass beads and was normally cooled to -160 C during sample collection. For the samples collected at Niles in this preliminary study, the cryo-trap was replaced with a two component adsorbent trap (Supelco #2-0321). This type of trap is normally employed for the analyses of VOCs in water when using purge and trap procedures. Previous Battelle work has also shown that this adsorbent combination works well in capturing and releasing ambient concentrations of the TO-14 species. Purging the trap with zero air after sample collection to dry the trap reduces residual moisture so that column plugging does not occur.

The analytical results from repeated injections of the preliminary canister samples did show much better precision than earlier work with the cryo-trap, however, several large components were still found to elute from the analytical column. These peaks were subsequently identified as column bleed peaks by the mass spectrometer (e.g. siloxane mass fragments). Battelle suspected that sufficient acidic gases were still present in the vapor phase to cause this column stripping to occur. Several column manufacturers have concurred that the bonded phase on the fused silica columns will be readily stripped in the presence of strong acids.

Further efforts were carried out to test an air scrubber placed ahead of the adsorbent trap. Previous studies at Battelle had indicated that a sodium bicarbonate (NaHCO_3) denuder worked very well in removing gaseous SO_2 from humidified air streams. The denuder system operated at flows of 10 to 20 liters/minute. At the low flow conditions required with the adsorbent trap (i.e. 15 cc/minute), a 10 cm long by 0.2 cm i.d. trap packed with 60/80 mesh NaHCO_3 was fabricated and placed in-line. Analytical results indicated much less peak artifacts. Results from the analyses of a 6 ppb standard mixture of TO-14 compounds with and without the NaHCO_3 scrubber also indicated reasonable agreement. No concentration differences were observed with benzene and toluene, however about a 20 percent loss was

observed with the less volatile species such as hexachlorobutadiene. Battelle believes that the less volatile TO-14 compounds are more likely to adhere to the NaHCO_3 surface.

Based upon the positive results with the NaHCO_3 scrubber, this device was inserted in-line for the analyses of all canister samples from the SNOX process.

7.4.2 Data Analysis

A total of 36 VOST and 36 canister samples were collected. Tables 7.4-1 through 7.4-12 show the results from analyzing individual canister samples. Tables 7.4-13 through 7.4-24 show the results from the VOST sample runs. Each table contains the three runs on the indicated date using the specified method. The "ND <" label indicates that the analyte was not detected. The detection level (DL) is indicated to the right of the label. For the VOST samples, the DL values changed as a function of the sampled volume. For the canister samples, the DL values remained constant because the same volume was always analyzed. In scanning the data, it is evident that the reported concentrations at several locations and on specific sampling days vary considerably from run to run with both methods. To examine the data further, three of the more frequently occurring compounds - dichloromethane, benzene and toluene - were selected and compared for the 36 runs. Table 7.4-25 shows these results. In viewing the table, a great deal of method run-to-run variability was evident for dichloromethane. However, for benzene and toluene, the method run-to-run concentration variability was reasonable and usually within a factor of two of each other. Concentrations between methods were usually within a factor of four. Furthermore, there does not appear to be a consistent bias between methods.

Dichloromethane (DCM) (50/50 with methanol) was used in the field study as a solvent to rinse sampling apparatus. It is suspected that the unreasonably high concentrations of DCM in the samples are probably due to contamination from this source. However, Battelle did not observe unreasonably high DCM in the field spike canister sample. In this case a portion of the trip spike was directed through the sampling manifold and into a second evacuated canister (i.e. field spike sample).

In order to determine if a bias exists between methods, the individual values from the three daily runs for benzene and toluene were first averaged and then compared. Figure

7.4-1 shows the results in bar graph form. The upper bar graph contains the benzene data; the lower bar graph contains the toluene data. The VOST and Can (canister) benzene daily averages are generally within a factor of two, except for Location 18 (second day) and Location 21 (second day). The toluene concentrations were frequently less than the detection level for both methods. However for Location 21 on days two and three, the Can toluene values were orders of magnitude higher than the VOST toluene values. The Can benzene concentration was also very high at Location 21 on day two. However, the value on day three was much lower. Excluding the above locations/days, the VOST benzene and toluene daily concentration averages were consistently higher than the Can values.

The benzene and toluene daily averages at each location were then averaged and the results are shown in Figure 7.4-2. The benzene location averages are depicted on the upper bar graph; the toluene location averages are shown on the lower bar graph. The VOST benzene results are higher than the canister benzene values at Locations 18 and 19. The VOST benzene results at Location 20 are lower than the canister values. Similar benzene concentrations for both methods were found at Location 20. Thus no method/benzene trend was observed at the locations. The toluene daily averages were near the detection limit except at Location 21. As mentioned earlier, Can toluene values from two of the three days at this location were unusually high.

7.4.3 Conclusions

The following conclusions are made from this study.

1. Dichloromethane concentrations are artifact values and are probably due to contamination from DCM/methanol washing of the sampling manifold and associated equipment.
2. The VOC, whether collected by VOST or canisters, in general show run to run concentration variability of a factor of two or less.

3. The VOST and canister collection methods generally agree within a factor of four. However, there does not seem to be a consistent trend between methods. This lack of a trend in the data may be due in part to the abnormally high benzene and toluene concentrations found in the canister samples from Location 21.

7.4.4 Recommendations

The following recommendations are made from the above analyses.

1. Greater care needs to be exerted to eliminate the solvent (dichloromethane) contamination or carry over into the sampling apparatus. This problem was consistently observed in both the VOST and canister sampling trains.
2. Battelle does not understand why both methods show such run to run variability. More internal QC checks may be helpful in focusing in on the problem. The use of internal standards spiked on the Tenax adsorbent or into the evacuated canister prior to sampling would aid in determining if reactions are occurring with the VOCs following sample collection.
3. The employment of an on-line continuous instrument (or almost continuous) for monitoring one or more of the VOCs would help a good deal in determining how much the VOC concentrations fluctuate in the flue gas stream. For example, a gas chromatograph equipped with a photoionization detector or mass selective detector could provide information on one or two VOC in less than 30 minutes from the end of sample collection.

TABLE 7.4-1.VOC IN SUMMA GAS SAMPLES FROM BAGHOUSE INLET (Location 18)-7/18/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N-18-CAN-718-1	N-18-CAN-718-2	N-18-CAN-718-3
Trichlorofluoromethane		66.06	67.05	129.58
1,1-Dichloroethene	ND<	2.51	ND<	2.51
Dichloromethane		155.94	78.81	42.56
3-Chloropropene		2.96	ND<	1.99
1,1,2-Trichloro-1,2,2-trifluoroethane		21.00	19.43	28.32
1,1-Dichloroethane	ND<	2.56	ND<	2.56
cis-1,2-dichloroethene	ND<	2.51	ND<	2.51
Trichloromethane	ND<	3.07	ND<	3.08
1,2-Dichloroethane	ND<	2.56	ND<	2.56
1,1,1-Trichloroethane		4.95	ND<	3.43
Benzene		6.51	6.51	7.87
Carbon tetrachloride	ND<	3.98	12.66	11.93
1,2-Dichloropropane	ND<	2.92	ND<	2.92
Trichloroethene	ND<	3.38	ND<	3.38
cis-1,3-Dichloropropene	ND<	2.86	ND<	2.86
trans-1,3-Dichloropropene	ND<	2.86	ND<	2.86
1,1,2-Trichloroethane	ND<	3.43	ND<	3.43
Toluene	ND<	2.37	ND<	2.37
1,2-Dibromoethane	ND<	4.85	ND<	4.86
Tetrachloroethene	ND<	4.28	ND<	4.29
Chlorobenzene		6.49	5.66	6.81
Ethylbenzene		8.89	ND<	2.74
m+p-Xylene		9.60	ND<	2.74
Styrene	ND<	2.68	ND<	2.68
1,1,2,2-Tetrachloroethane	ND<	4.34	ND<	4.34
o-Xylene		3.16	ND<	2.74
4-Ethyl toluene	ND<	3.10	ND<	3.39
1,3,5-Trimethylbenzene	ND<	3.10	ND<	3.10
1,2,4-Trimethylbenzene	ND<	3.10	ND<	3.10
Benzyl chloride	ND<	3.28	ND<	3.27
m-Dichlorobenzene	ND<	3.79	ND<	3.79
p-Dichlorobenzene	ND<	3.79	ND<	3.79
o-Dichlorobenzene	ND<	3.79	ND<	4.69
1,2,4-Trichlorobenzene	ND<	4.67	ND<	4.67
Hexachlorobutadiene	ND<	6.73	ND<	6.73

ND< = not detected, value following ND< is the detection limit.

TABLE 7.4-2. VOC IN SUMMA GAS SAMPLES FROM BAGHOUSE INLET(Location 18)-7/21/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-18-CAN-721-1		N-18-CAN-721-2		N-18-CAN-721-3	
Trichlorofluoromethane	ND<	3.64		4.75		4.17
1,1-Dichloroethene	ND<	2.58	ND<	2.58	ND<	2.58
Dichloromethane		113.31		14.47		18.49
3-Chloropropene		3.04	ND<	2.05		2.49
1,1,2-Trichloro-1,2,2-trifluoroethane		13.94		53.21		14.12
1,1-Dichloroethane	ND<	2.63	ND<	2.63	ND<	2.63
cis-1,2-dichloroethene	ND<	2.58	ND<	2.58	ND<	2.58
Trichloromethane	ND<	3.17	ND<	3.17		23.39
1,2-Dichloroethane	ND<	2.63	ND<	2.63	ND<	2.63
1,1,1-Trichloroethane	ND<	3.54	ND<	3.54	ND<	3.54
Benzene		8.11		9.28		13.29
Carbon tetrachloride	ND<	4.10	ND<	4.10	ND<	4.10
1,2-Dichloropropane	ND<	3.00	ND<	3.00	ND<	3.00
Trichloroethene	ND<	3.49	ND<	3.49	ND<	3.49
cis-1,3-Dichloropropene	ND<	2.95	ND<	2.95	ND<	2.95
trans-1,3-Dichloropropene	ND<	2.95	ND<	2.95	ND<	2.95
1,1,2-Trichloroethane	ND<	3.54	ND<	3.54	ND<	3.54
Toluene	ND<	2.44	ND<	2.44	ND<	2.44
1,2-Dibromoethane	ND<	5.00	ND<	5.00	ND<	5.00
Tetrachloroethene	ND<	4.42	ND<	4.42	ND<	4.42
Chlorobenzene		3.66	ND<	3.00	ND<	3.00
Ethylbenzene	ND<	2.82	ND<	2.82	ND<	2.82
m+p-Xylene	ND<	2.82	ND<	2.82	ND<	2.82
Styrene	ND<	2.76	ND<	2.76	ND<	2.76
1,1,2,2-Tetrachloroethane	ND<	4.47	ND<	4.47	ND<	4.47
o-Xylene	ND<	2.82	ND<	2.82	ND<	2.82
4-Ethyl toluene	ND<	3.19	ND<	3.19	ND<	3.19
1,3,5-Trimethylbenzene	ND<	3.19	ND<	3.19	ND<	3.19
1,2,4-Trimethylbenzene		3.70	ND<	3.19	ND<	3.19
Benzyl chloride	ND<	3.37	ND<	3.37	ND<	3.37
m-Dichlorobenzene	ND<	3.91	ND<	3.91	ND<	3.91
p-Dichlorobenzene	ND<	3.91	ND<	3.91	ND<	3.91
o-Dichlorobenzene	ND<	3.91	ND<	3.91	ND<	3.91
1,2,4-Trichlorobenzene	ND<	4.81	ND<	4.81	ND<	4.81
Hexachlorobutadiene	ND<	6.94	ND<	6.94	ND<	6.94

TABLE 7.4-3. VOC IN SUMMA GAS SAMPLES FROM BAGHOUSE INLET (Location 18)-7/23/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-18-CAN-723-1		N-18-CAN-723-2		N-18-CAN-723-3	
Trichlorofluoromethane		3.56		4.86		5.84
1,1-Dichloroethene	ND<	2.34	ND<	2.34	ND<	2.34
Dichloromethane		886.38 E		239.76		139.61
3-Chloropropene		4.93		7.22		5.78
1,1,2-Trichloro-1,2,2-trifluoroethane		10.47		14.54		15.76
1,1-Dichloroethane	ND<	2.39	ND<	2.39	ND<	2.39
cis-1,2-dichloroethene	ND<	2.34	ND<	2.34	ND<	2.34
Trichloromethane	ND<	2.87	ND<	2.87	ND<	2.87
1,2-Dichloroethane	ND<	2.39	ND<	2.39	ND<	2.39
1,1,1-Trichloroethane	ND<	3.21	ND<	3.21	ND<	3.21
Benzene		7.44		10.74		10.54
Carbon tetrachloride	ND<	3.71	ND<	3.71	ND<	3.71
1,2-Dichloropropane	ND<	2.72	ND<	2.72	ND<	2.72
Trichloroethene	ND<	3.16	ND<	3.16	ND<	3.16
cis-1,3-Dichloropropene	ND<	2.67	ND<	2.67	ND<	2.67
trans-1,3-Dichloropropene	ND<	2.67	ND<	2.67	ND<	2.67
1,1,2-Trichloroethane	ND<	3.21	ND<	3.21	ND<	3.21
Toluene	ND<	2.22	ND<	2.22	ND<	2.22
1,2-Dibromoethane	ND<	4.53	ND<	4.53	ND<	4.53
Tetrachloroethene	ND<	4.00	ND<	4.00	ND<	4.00
Chlorobenzene	ND<	2.72	ND<	2.72	ND<	2.72
Ethylbenzene	ND<	2.56	ND<	2.56	ND<	2.56
m+p-Xylene	ND<	2.56	ND<	2.56	ND<	2.56
Styrene	ND<	2.50	ND<	2.50	ND<	2.50
1,1,2,2-Tetrachloroethane	ND<	4.05	ND<	4.05	ND<	4.05
o-Xylene	ND<	2.56	ND<	2.56	ND<	2.56
4-Ethyl toluene	ND<	2.89	ND<	2.89		3.20
1,3,5-Trimethylbenzene	ND<	2.89	ND<	2.89	ND<	2.89
1,2,4-Trimethylbenzene	ND<	2.89	ND<	2.89	ND<	2.89
Benzyl chloride	ND<	3.06	ND<	3.06	ND<	3.06
m-Dichlorobenzene	ND<	3.54	ND<	3.54	ND<	3.54
p-Dichlorobenzene	ND<	3.54	ND<	3.54	ND<	3.54
o-Dichlorobenzene	ND<	3.54	ND<	3.54	ND<	3.54
1,2,4-Trichlorobenzene	ND<	4.36	ND<	4.36	ND<	4.36
Hexachlorobutadiene	ND<	6.29	ND<	6.29	ND<	6.29

TABLE 7.4-4. VOC IN SUMMA GAS SAMPLES FROM BAGHOUSE OUTLET(Location 19)-7/18/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N-19-CAN-718-1	N-19-CAN-718-2	N-19-CAN-718-3
Trichlorofluoromethane		82.14	90.06	82.99
1,1-Dichloroethene	ND<	2.63	2.63	2.63
Dichloromethane		544.69	368.11	117.66
3-Chloropropene		13.48	3.85	3.63
1,1,2-Trichloro-1,2,2-trifluoroethane		238.58	278.96	167.88
1,1-Dichloroethane	ND<	2.68	2.68	2.68
cis-1,2-dichloroethene	ND<	2.63	2.63	2.63
Trichloromethane	ND<	3.23	3.23	3.23
1,2-Dichloroethane	ND<	2.68	2.68	2.68
1,1,1-Trichloroethane	ND<	3.60	3.60	3.60
Benzene		29.13	30.67	15.54
Carbon tetrachloride		15.48	24.74	6.85
1,2-Dichloropropane	ND<	3.06	3.06	3.06
Trichloroethene	ND<	3.55	3.55	3.55
cis-1,3-Dichloropropene	ND<	3.01	3.01	3.01
trans-1,3-Dichloropropene	ND<	3.01	3.01	3.01
1,1,2-Trichloroethane	ND<	3.60	3.60	3.60
Toluene	ND<	2.49	2.49	2.49
1,2-Dibromoethane	ND<	5.09	5.84	5.09
Tetrachloroethene	ND<	4.50	4.50	4.50
Chlorobenzene		8.23	10.69	5.61
Ethylbenzene	ND<	2.87	2.87	2.88
m+p-Xylene	ND<	2.87	2.87	2.88
Styrene	ND<	2.82	2.82	2.82
1,1,2,2-Tetrachloroethane	ND<	4.55	4.55	4.55
o-Xylene	ND<	2.87	2.87	2.88
4-Ethyl toluene	ND<	3.25	3.25	3.25
1,3,5-Trimethylbenzene	ND<	3.25	3.25	3.25
1,2,4-Trimethylbenzene		12.71	3.25	3.25
Benzyl chloride		9.46	3.44	3.44
m-Dichlorobenzene	ND<	3.98	3.98	3.98
p-Dichlorobenzene	ND<	3.98	3.98	3.98
o-Dichlorobenzene		4.08	4.71	3.98
1,2,4-Trichlorobenzene	ND<	4.90	4.90	4.90
Hexachlorobutadiene	ND<	7.07	7.07	7.07

TABLE 7.4-5. VOC IN SUMMA GAS SAMPLES FROM BAGHOUSE OUTLET (Location 19)-7/21/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-19-CAN-721-1		N-19-CAN-721-2		N-19-CAN-721-3	
Trichlorofluoromethane		4.60		4.66		4.39
1,1-Dichloroethene	ND<	2.55	ND<	2.55	ND<	2.55
Dichloromethane		96.63		8.92		8.52
3-Chloropropene		4.74	ND<	2.02	ND<	2.02
1,1,2-Trichloro-1,2,2-trifluoroethane		105.99		95.06		97.00
1,1-Dichloroethane	ND<	2.60	ND<	2.60	ND<	2.60
cis-1,2-dichloroethene	ND<	2.55	ND<	2.55	ND<	2.55
Trichloromethane	ND<	3.13	ND<	3.13	ND<	3.13
1,2-Dichloroethane	ND<	2.60	ND<	2.60	ND<	2.60
1,1,1-Trichloroethane	ND<	3.49	ND<	3.49	ND<	3.49
Benzene		9.34		8.80		10.79
Carbon tetrachloride	ND<	4.05	ND<	4.05	ND<	4.05
1,2-Dichloropropane	ND<	2.97	ND<	2.97	ND<	2.97
Trichloroethene	ND<	3.44	ND<	3.44	ND<	3.44
cis-1,3-Dichloropropene		8.36	ND<	2.92	ND<	2.92
trans-1,3-Dichloropropene	ND<	2.92	ND<	2.92	ND<	2.92
1,1,2-Trichloroethane	ND<	3.49	ND<	3.49	ND<	3.49
Toluene	ND<	2.42	ND<	2.42	ND<	2.42
1,2-Dibromoethane	ND<	4.94	ND<	4.94	ND<	4.94
Tetrachloroethene	ND<	4.36	ND<	4.36	ND<	4.37
Chlorobenzene	ND<	2.97	ND<	2.97	ND<	2.97
Ethylbenzene	ND<	2.79	ND<	2.79	ND<	2.79
m+p-Xylene	ND<	2.79	ND<	2.79	ND<	2.79
Styrene	ND<	2.73	ND<	2.73	ND<	2.73
1,1,2,2-Tetrachloroethane	ND<	4.41	ND<	4.41	ND<	4.41
o-Xylene	ND<	2.79	ND<	2.79	ND<	2.79
4-Ethyl toluene	ND<	3.15	ND<	3.15	ND<	3.15
1,3,5-Trimethylbenzene	ND<	3.15	ND<	3.15	ND<	3.15
1,2,4-Trimethylbenzene		33.11		15.63	ND<	3.15
Benzyl chloride		23.60		12.75	ND<	3.33
m-Dichlorobenzene		7.72	ND<	3.86	ND<	3.86
p-Dichlorobenzene		9.65		4.68	ND<	3.86
o-Dichlorobenzene	ND<	3.86	ND<	3.86	ND<	3.86
1,2,4-Trichlorobenzene	ND<	4.75	ND<	4.75	ND<	4.75
Hexachlorobutadiene	ND<	6.85	ND<	6.85	ND<	6.85

TABLE 7.4-6. VOC IN SUMMA GAS SAMPLES FROM BAGHOUSE OUTLET (Location 19)-7/23/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-19-CAN-723-1		N-19-CAN-723-2		N-19-CAN-723-3	
Trichlorofluoromethane		3.67		3.98		3.64
1,1-Dichloroethene	ND<	2.51	ND<	2.51	ND<	2.51
Dichloromethane		99.94		18.63		10.04
3-Chloropropene		3.49		12.29		14.15
1,1,2-Trichloro-1,2,2-trifluoroethane		35.79		37.19		39.10
1,1-Dichloroethane	ND<	2.56	ND<	2.56	ND<	2.56
cis-1,2-dichloroethene	ND<	2.51	ND<	2.51	ND<	2.51
Trichloromethane	ND<	3.07	ND<	3.07	ND<	3.08
1,2-Dichloroethane	ND<	2.56	ND<	2.56	ND<	2.56
1,1,1-Trichloroethane	ND<	3.43	ND<	3.43	ND<	3.43
Benzene		8.09		10.15		7.58
Carbon tetrachloride	ND<	3.98	ND<	3.98	ND<	3.98
1,2-Dichloropropane	ND<	2.92	ND<	2.92	ND<	2.92
Trichloroethene	ND<	3.38	ND<	3.38	ND<	3.38
cis-1,3-Dichloropropene	ND<	2.86	ND<	2.86	ND<	2.86
trans-1,3-Dichloropropene	ND<	2.86	ND<	2.86	ND<	2.86
1,1,2-Trichloroethane	ND<	3.43	ND<	3.43	ND<	3.43
Toluene	ND<	2.37	ND<	2.37	ND<	2.37
1,2-Dibromoethane	ND<	4.85	ND<	4.85	ND<	4.86
Tetrachloroethene	ND<	4.28	ND<	4.28	ND<	4.29
Chlorobenzene	ND<	2.92	ND<	2.92	ND<	2.92
Ethylbenzene	ND<	2.74	ND<	2.74	ND<	2.74
m+p-Xylene	ND<	2.74	ND<	2.74	ND<	2.74
Styrene	ND<	2.68	ND<	2.68	ND<	2.68
1,1,2,2-Tetrachloroethane	ND<	4.34	ND<	4.34	ND<	4.34
o-Xylene	ND<	2.74	ND<	2.74	ND<	2.74
4-Ethyl toluene	ND<	3.10	ND<	3.10	ND<	3.10
1,3,5-Trimethylbenzene	ND<	3.10	ND<	3.10	ND<	3.10
1,2,4-Trimethylbenzene		5.37		4.00	ND<	3.10
Benzyl chloride		3.99	ND<	3.28	ND<	3.28
m-Dichlorobenzene	ND<	3.79	ND<	3.79	ND<	3.79
p-Dichlorobenzene	ND<	3.79	ND<	3.79	ND<	3.79
o-Dichlorobenzene	ND<	3.79	ND<	3.79	ND<	3.79
1,2,4-Trichlorobenzene	ND<	4.67	ND<	4.67	ND<	4.67
Hexachlorobutadiene	ND<	6.73	ND<	6.73	ND<	6.73

TABLE 7.4-7. VOC IN SUMMA GAS SAMPLES FROM SCR REACTOR OUTLET (Location 20) - 7/18/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-20-CAN-718-1		N-20-CAN-718-2		N-20-CAN-718-3	
Trichlorofluoromethane	ND<	4.01		4.51		9.11
1,1-Dichloroethene	ND<	2.84	ND<	2.84	ND<	2.84
Dichloromethane		396.73		3.87		31.57
3-Chloropropene		4.04	ND<	2.25	ND<	2.25
1,1,2-Trichloro-1,2,2-trifluoroethane		8.65		11.78		35.55
1,1-Dichloroethane	ND<	2.90	ND<	2.90	ND<	2.90
cis-1,2-dichloroethene	ND<	2.84	ND<	2.84	ND<	2.84
Trichloromethane	ND<	3.49	ND<	3.49	ND<	3.49
1,2-Dichloroethane	ND<	2.90	ND<	2.90	ND<	2.90
1,1,1-Trichloroethane	ND<	3.89	ND<	3.89		23.46
Benzene		40.95	ND<	2.28		7.35
Carbon tetrachloride	ND<	4.51	ND<	4.51	ND<	4.51
1,2-Dichloropropane	ND<	3.31	ND<	3.31	ND<	3.31
Trichloroethene	ND<	3.84	ND<	3.84	ND<	3.84
cis-1,3-Dichloropropene	ND<	3.25	ND<	3.25	ND<	3.25
trans-1,3-Dichloropropene	ND<	3.25	ND<	3.25	ND<	3.25
1,1,2-Trichloroethane	ND<	3.89	ND<	3.89	ND<	3.89
Toluene		15.43	ND<	2.69		3.17
1,2-Dibromoethane	ND<	5.50	ND<	5.50	ND<	5.51
Tetrachloroethene	ND<	4.86	ND<	4.86	ND<	4.87
Chlorobenzene	ND<	3.31	ND<	3.31	ND<	3.31
Ethylbenzene	ND<	3.11	ND<	3.11	ND<	3.11
m+p-Xylene	ND<	3.11	ND<	3.11	ND<	3.11
Styrene	ND<	3.04	ND<	3.04	ND<	3.04
1,1,2,2-Tetrachloroethane	ND<	4.92	ND<	4.92	ND<	4.92
o-Xylene	ND<	3.11	ND<	3.11	ND<	3.11
4-Ethyl toluene	ND<	3.51	ND<	3.51	ND<	3.51
1,3,5-Trimethylbenzene	ND<	3.51	ND<	3.51	ND<	3.51
1,2,4-Trimethylbenzene	ND<	3.51	ND<	3.51	ND<	3.51
Benzyl chloride	ND<	3.71	ND<	3.71	ND<	3.71
m-Dichlorobenzene	ND<	4.30	ND<	4.30	ND<	4.30
p-Dichlorobenzene	ND<	4.30	ND<	4.30	ND<	4.30
o-Dichlorobenzene	ND<	4.30	ND<	4.30	ND<	4.30
1,2,4-Trichlorobenzene	ND<	5.30	ND<	5.30	ND<	5.30
Hexachlorobutadiene	ND<	7.64	ND<	7.64	ND<	7.64

TABLE 7.4-8. VOC IN

<u>Compound</u>
Trichlorofluoromethane
1,1-Dichloroethene
Dichloromethane
3-Chloropropene
1,1,2-Trichloro-1,2,
1,1-Dichloroethane
cis-1,2-dichloroethane
Trichloromethane
1,2-Dichloroethane
1,1,1-Trichloroethane
Benzene

TABLE 7.4-9. VOC IN SUMMA GAS SAMPLES FROM SCR REACTOR OUTLET (Location 20) - 7/23/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N-20-CAN-723-1	N-20-CAN-723-2	N-20-CAN-723-3
Trichlorofluoromethane		5.31	4.89	5.08
1,1-Dichloroethene	ND<	3.05	ND<	3.05
Dichloromethane		251.79	115.82	178.22
3-Chloropropene		4.77	14.16	23.86
1,1,2-Trichloro-1,2,2-trifluoroethane		13.65	12.74	11.27
1,1-Dichloroethane	ND<	3.11	ND<	3.11
cis-1,2-dichloroethene	ND<	3.05	ND<	3.05
Trichloromethane	ND<	3.74	ND<	3.74
1,2-Dichloroethane	ND<	3.11	ND<	3.11
1,1,1-Trichloroethane	ND<	4.17	ND<	4.17
Benzene	ND<	2.45	ND<	2.45
Carbon tetrachloride	ND<	4.83	ND<	4.83
1,2-Dichloropropane	ND<	3.54	ND<	3.54
Trichloroethene	ND<	4.11	ND<	4.11
cis-1,3-Dichloropropene	ND<	3.48	ND<	3.48
trans-1,3-Dichloropropene	ND<	3.48	ND<	3.48
1,1,2-Trichloroethane	ND<	4.17	ND<	4.17
Toluene	ND<	2.88	ND<	2.88
1,2-Dibromoethane	ND<	5.90	ND<	5.90
Tetrachloroethene	ND<	5.21	ND<	5.22
Chlorobenzene	ND<	3.54	ND<	3.54
Ethylbenzene	ND<	3.33	ND<	3.33
m+p-Xylene	ND<	3.33	ND<	3.33
Styrene	ND<	3.26	ND<	3.26
1,1,2,2-Tetrachloroethane	ND<	5.27	ND<	5.27
o-Xylene	ND<	3.33	ND<	3.33
4-Ethyl toluene	ND<	3.77	ND<	3.77
1,3,5-Trimethylbenzene	ND<	3.77	ND<	3.77
1,2,4-Trimethylbenzene	ND<	3.77	ND<	3.77
Benzyl chloride	ND<	3.98	ND<	3.98
m-Dichlorobenzene	ND<	4.61	ND<	4.61
p-Dichlorobenzene	ND<	4.61	ND<	4.61
o-Dichlorobenzene	ND<	4.61	ND<	4.61
1,2,4-Trichlorobenzene	ND<	5.68	ND<	5.68
Hexachlorobutadiene	ND<	8.19	ND<	8.19

TABLE 7.4-10. VOC IN SUMMA GAS SAMPLES FROM WSA TOWER OUTLET (Location 21) -7/18/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-21-CAN-718-1		N-21-CAN-718-2		N-21-CAN-718-3	
Trichlorofluoromethane	ND*	3.76		3.90		4.00
1,1-Dichloroethene	ND*	2.66	ND*	2.66	ND*	2.66
Dichloromethane		314.61		220.78		180.47
3-Chloropropene		7.56		5.19		3.30
1,1,2-Trichloro-1,2,2-trifluoroethane		11.18		11.84		11.99
1,1-Dichloroethane	ND*	2.72	ND*	2.72	ND*	2.72
cis-1,2-dichloroethene	ND*	2.66	ND*	2.66	ND*	2.66
Trichloromethane	ND*	3.27	ND*	3.27	ND*	3.27
1,2-Dichloroethane	ND*	2.72	ND*	2.72	ND*	2.72
1,1,1-Trichloroethane	ND*	3.65	ND*	3.65	ND*	3.65
Benzene		2.31	ND*	2.14	ND*	2.14
Carbon tetrachloride	ND*	4.23	ND*	4.23	ND*	4.23
1,2-Dichloropropane	ND*	3.10	ND*	3.10	ND*	3.10
Trichloroethene	ND*	3.60	ND*	3.60	ND*	3.60
cis-1,3-Dichloropropene	ND*	3.05	ND*	3.05	ND*	3.05
trans-1,3-Dichloropropene	ND*	3.05	ND*	3.05	ND*	3.05
1,1,2-Trichloroethane	ND*	3.65	ND*	3.65	ND*	3.65
Toluene	ND*	2.52	ND*	2.52	ND*	2.52
1,2-Dibromoethane	ND*	5.16	ND*	5.16	ND*	5.16
Tetrachloroethene	ND*	4.55	ND*	4.55	ND*	4.56
Chlorobenzene	ND*	3.10	ND*	3.10	ND*	3.10
Ethylbenzene	ND*	2.91	ND*	2.91	ND*	2.91
m+p-Xylene	ND*	2.91	ND*	2.91	ND*	2.91
Styrene	ND*	2.85	ND*	2.85	ND*	2.85
1,1,2,2-Tetrachloroethane	ND*	4.61	ND*	4.61	ND*	4.61
o-Xylene	ND*	2.91	ND*	2.91	ND*	2.91
4-Ethyl toluene	ND*	3.29	ND*	3.29	ND*	3.29
1,3,5-Trimethylbenzene	ND*	3.29	ND*	3.29	ND*	3.29
1,2,4-Trimethylbenzene	ND*	3.29	ND*	3.29	ND*	3.29
Benzyl chloride	ND*	3.48	ND*	3.48	ND*	3.48
m-Dichlorobenzene	ND*	4.03	ND*	4.03	ND*	4.03
p-Dichlorobenzene	ND*	4.03	ND*	4.03	ND*	4.03
o-Dichlorobenzene	ND*	4.03	ND*	4.03	ND*	4.03
1,2,4-Trichlorobenzene	ND*	4.96	ND*	4.96	ND*	4.96
Hexachlorobutadiene	ND*	7.16	ND*	7.16	ND*	7.16

TABLE 7.4-11. VOC IN SUMMA GAS SAMPLES FROM WSA TOWER OUTLET (Location 21) -7/21/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N-21-CAN-721-1		N-21-CAN-721-2		N-21-CAN-721-3	
Trichlorofluoromethane		5.04		5.67		8.57
1,1-Dichloroethene	ND<	3.05	ND<	3.05	ND<	3.05
Dichloromethane		1932.23 E		1205.88 E		1635.56 E
3-Chloropropene		56.28		35.52		48.73
1,1,2-Trichloro-1,2,2-trifluoroethane		14.60		17.70		25.93
1,1-Dichloroethane	ND<	3.11	ND<	3.11	ND<	3.11
cis-1,2-dichloroethene	ND<	3.05	ND<	3.05	ND<	3.05
Trichloromethane	ND<	3.74	ND<	3.74	ND<	3.74
1,2-Dichloroethane	ND<	3.11	ND<	3.11	ND<	3.11
1,1,1-Trichloroethane	ND<	4.17	ND<	4.17	ND<	4.17
Benzene		74.20		38.54		127.57
Carbon tetrachloride	ND<	4.83	ND<	4.83	ND<	4.83
1,2-Dichloropropane	ND<	3.54	ND<	3.54	ND<	3.54
Trichloroethene	ND<	4.11	ND<	4.11	ND<	4.11
cis-1,3-Dichloropropene	ND<	3.48	ND<	3.48	ND<	3.48
trans-1,3-Dichloropropene	ND<	3.48	ND<	3.48	ND<	3.48
1,1,2-Trichloroethane	ND<	4.17	ND<	4.17	ND<	4.17
Toluene		19.27	ND<	2.88		990.77 E
1,2-Dibromoethane	ND<	5.90	ND<	5.90	ND<	5.90
Tetrachloroethene	ND<	5.21	ND<	5.21	ND<	5.22
Chlorobenzene	ND<	3.54	ND<	3.54	ND<	3.54
Ethylbenzene	ND<	3.33	ND<	3.33	ND<	3.33
m+p-Xylene	ND<	3.33	ND<	3.33	ND<	3.33
Styrene	ND<	3.26	ND<	3.26	ND<	3.26
1,1,2,2-Tetrachloroethane	ND<	5.27	ND<	5.27	ND<	5.27
o-Xylene	ND<	3.33	ND<	3.33	ND<	3.33
4-Ethyl toluene	ND<	3.77	ND<	3.77		13.51
1,3,5-Trimethylbenzene	ND<	3.77	ND<	3.77	ND<	3.77
1,2,4-Trimethylbenzene	ND<	3.77	ND<	3.77	ND<	3.77
Benzyl chloride	ND<	3.98	ND<	3.98	ND<	3.98
m-Dichlorobenzene	ND<	4.61	ND<	4.61	ND<	4.61
p-Dichlorobenzene	ND<	4.61	ND<	4.61	ND<	4.61
o-Dichlorobenzene	ND<	4.61	ND<	4.61	ND<	4.61
1,2,4-Trichlorobenzene	ND<	5.68	ND<	5.68	ND<	5.68
Hexachlorobutadiene	ND<	8.19	ND<	8.19	ND<	8.19

TABLE 7.4-12. VOC IN SUMMA GAS SAMPLES FROM WSA TOWER OUTLET (Location 21) -7/23/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N-21-CAN-723-1	N-21-CAN-723-2	N-21-CAN-723-3
Trichlorofluoromethane		4.43	4.19	4.22
1,1-Dichloroethene	ND	2.66	2.66	2.66
Dichloromethane		3829.46 E	3816.97 E	3997.62 E
3-Chloropropene		4.32	4.02	14.06
1,1,2-Trichloro-1,2,2-trifluoroethane		9.47	10.12	9.50
1,1-Dichloroethane	ND	2.72	2.72	2.72
cis-1,2-dichloroethene	ND	2.66	2.66	2.66
Trichloromethane	ND	3.27	3.27	3.27
1,2-Dichloroethane	ND	2.72	2.72	2.72
1,1,1-Trichloroethane		5.49	3.65	3.65
Benzene		4.79	2.14	2.14
Carbon tetrachloride	ND	4.23	4.23	4.23
1,2-Dichloropropane	ND	3.10	3.10	3.10
Trichloroethene	ND	3.60	3.60	3.60
cis-1,3-Dichloropropene	ND	3.05	3.05	3.05
trans-1,3-Dichloropropene	ND	3.05	3.31	3.05
1,1,2-Trichloroethane	ND	3.65	3.65	3.65
Toluene		700.47 E	835.45 E	778.82 E
1,2-Dibromoethane	ND	5.16	5.16	5.16
Tetrachloroethene	ND	4.55	4.55	4.56
Chlorobenzene	ND	3.10	3.10	3.10
Ethylbenzene	ND	2.91	2.91	2.98
m+p-Xylene	ND	2.91	2.91	3.11
Styrene	ND	2.85	2.85	2.85
1,1,2,2-Tetrachloroethane	ND	4.61	4.61	4.61
o-Xylene	ND	2.91	2.91	2.91
4-Ethyl toluene	ND	3.29	10.43	14.59
1,3,5-Trimethylbenzene	ND	3.29	3.29	3.29
1,2,4-Trimethylbenzene	ND	3.29	3.29	3.29
Benzyl chloride	ND	3.48	15.22	3.48
m-Dichlorobenzene	ND	4.03	4.03	4.03
p-Dichlorobenzene	ND	4.03	4.03	4.03
o-Dichlorobenzene	ND	4.03	4.03	4.03
1,2,4-Trichlorobenzene	ND	4.96	4.96	4.96
Hexachlorobutadiene	ND	7.16	7.16	7.16

TABLE 7.4-13. VOC IN VOST GAS SAMPLES FROM BAGHOUSE INLET (Location 18)-7/18/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N18VOS7181		N18VOS7182		N18VOS7183	
CHLOROMETHANE	ND<	8.20	ND<	5.42	ND<	1.77
BROMOMETHANE	ND<	8.20	ND<	5.42	ND<	1.77
VINYL CHLORIDE	ND<	8.20	ND<	5.42	ND<	1.77
CHLOROETHANE	ND<	8.20	ND<	5.42	ND<	1.77
METHYLENE CHLORIDE		69.13		25.38		7.71
ACETONE		73.35		88.94		21.51
CARBON DISULFIDE		7.54 J	ND<	5.42		10.54
1,1-DICHLOROETHENE	ND<	8.20	ND<	5.42	ND<	1.77
1,1-DICHLOROETHANE	ND<	8.20	ND<	5.42	ND<	1.77
TRANS-1,2-DICHLOROETHENE	ND<	8.20	ND<	5.42	ND<	1.77
CHLOROFORM	ND<	8.20		3.91 J		0.92 J
1,2-DICHLOROETHANE	ND<	8.20	ND<	5.42	ND<	1.77
2-BUTANONE	ND<	8.20	ND<	5.42	ND<	1.77
1,1,1-TRICHLOROETHANE		4.58 J	ND<	5.42	ND<	1.77
CARBON TETRACHLORIDE		4.91 J		2.60 J	ND<	1.77
VINYL ACETATE	ND<	8.20	ND<	5.42	ND<	1.77
BROMODICHLOROMETHANE	ND<	8.20	ND<	5.42	ND<	1.77
1,2-DICHLOROPROPANE	ND<	8.20	ND<	5.42	ND<	1.77
CIS-1,3-DICHLOROPROPANE	ND<	8.20	ND<	5.42	ND<	1.77
TRICHLOROETHENE	ND<	8.20	ND<	5.42	ND<	1.77
DIBROMOCHLOROMETHANE	ND<	8.20	ND<	5.42	ND<	1.77
1,1,2-TRICHLOROETHANE	ND<	8.20	ND<	5.42	ND<	1.77
BENZENE		21.95		17.36		13.58
TRANS-1,3-DICHLOROPROPANE	ND<	8.20	ND<	5.42	ND<	1.77
2-CHLOROETHYL VINYLETHER	ND<	8.20	ND<	5.42	ND<	1.77
BROMOFORM	ND<	8.20	ND<	5.42	ND<	1.77
4-METHYL-2-PENTANONE		5.57 J		4.13 J		2.26
2-HEXANONE		11.47		8.24		3.54
TETRACHLOROETHENE	ND<	8.20	ND<	5.42	ND<	1.77
1,1,2,2-TETRACHLOROETHANE	ND<	8.20	ND<	5.42	ND<	1.77
TOLUENE		16.71		5.64		2.83
CHLOROBENZENE	ND<	8.20	ND<	5.42	ND<	1.77
ETHYLBENZENE		3.60 J	ND<	5.42	ND<	1.77
STYRENE	ND<	8.20	ND<	5.42	ND<	1.77
XYLENES (TOTAL)		15.72	ND<	5.42		1.84

TABLE 7.4-14. VOC IN VOST GAS SAMPLES FROM BAGHOUSE INLET (Location 18)-7/21/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N18VOS7211		N18VOS7212		N18VOS7213	
CHLOROMETHANE	ND<	7.43	ND<	4.95	ND<	1.74
BROMOMETHANE	ND<	7.43	ND<	4.95	ND<	1.74
VINYL CHLORIDE	ND<	7.43	ND<	4.95	ND<	1.74
CHLOROETHANE	ND<	7.43	ND<	4.95	ND<	1.74
METHYLENE CHLORIDE		32.71		9.30	ND<	1.74
ACETONE		120.71	ND<	4.95		17.91
CARBON DISULFIDE		14.87		14.24		7.71
1,1-DICHLOROETHENE	ND<	7.43	ND<	4.95	ND<	1.74
1,1-DICHLOROETHANE	ND<	7.43	ND<	4.95	ND<	1.74
TRANS-1,2-DICHLOROETHENE	ND<	7.43	ND<	4.95	ND<	1.74
CHLOROFORM	ND<	7.43	ND<	4.95	ND<	1.74
1,2-DICHLOROETHANE	ND<	7.43	ND<	4.95	ND<	1.74
2-BUTANONE	ND<	7.43	ND<	4.95	ND<	1.74
1,1,1-TRICHLOROETHANE	ND<	7.43	ND<	4.95	ND<	1.74
CARBON TETRACHLORIDE	ND<	7.43	ND<	4.95	ND<	1.74
VINYL ACETATE	ND<	7.43	ND<	4.95	ND<	1.74
BROMODICHLOROMETHANE	ND<	7.43	ND<	4.95	ND<	1.74
1,2-DICHLOROPROPANE	ND<	7.43	ND<	4.95	ND<	1.74
CIS-1,3-DICHLOROPROPANE	ND<	7.43	ND<	4.95	ND<	1.74
TRICHLOROETHENE	ND<	7.43	ND<	4.95	ND<	1.74
DIBROMOCHLOROMETHANE	ND<	7.43	ND<	4.95	ND<	1.74
1,1,2-TRICHLOROETHANE	ND<	7.43	ND<	4.95	ND<	1.74
BENZENE		63.92		99.14	ND<	1.74
TRANS-1,3-DICHLOROPROPANE	ND<	7.43	ND<	4.95	ND<	1.74
2-CHLOROETHYLVINYLETHER	ND<	7.43	ND<	4.95	ND<	1.74
BROMOFORM	ND<	7.43	ND<	4.95	ND<	1.74
4-METHYL-2-PENTANONE	ND<	7.43	ND<	4.95	ND<	1.74
2-HEXANONE	ND<	7.43	ND<	4.95	ND<	1.74
TETRACHLOROETHENE	ND<	7.43	ND<	4.95	ND<	1.74
1,1,2,2-TETRACHLOROETHANE	ND<	7.43	ND<	4.95	ND<	1.74
TOLUENE	ND<	7.43	ND<	4.95	ND<	1.74
CHLOROBENZENE	ND<	7.43	ND<	4.95	ND<	1.74
ETHYLBENZENE	ND<	7.43	ND<	4.95	ND<	1.74
STYRENE	ND<	7.43	ND<	4.95	ND<	1.74
XYLENES (TOTAL)	ND<	7.43	ND<	4.95	ND<	1.74

TABLE 7.4-15. VOC IN VOST GAS SAMPLES FROM BAGHOUSE INLET (Location 18)-7/23/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N18V0S7231		N18V0S7232		N18V0S7233	
CHLOROMETHANE	ND<	7.85	ND<	4.28	ND<	1.60
BROMOMETHANE	ND<	7.85	ND<	4.28	ND<	1.60
VINYL CHLORIDE	ND<	7.85	ND<	4.28	ND<	1.60
CHLOROETHANE	ND<	7.85	ND<	4.28	ND<	1.60
METHYLENE CHLORIDE		28.27		15.41		7.04
ACETONE		47.73		16.78		42.38
CARBON DISULFIDE		22.61		26.53		24.34
1,1-DICHLOROETHENE	ND<	7.85	ND<	4.28	ND<	1.60
1,1-DICHLOROETHANE	ND<	7.85	ND<	4.28	ND<	1.60
TRANS-1,2-DICHLOROETHENE	ND<	7.85	ND<	4.28	ND<	1.60
CHLOROFORM	ND<	7.85	ND<	4.28	ND<	1.60
1,2-DICHLOROETHANE	ND<	7.85	ND<	4.28	ND<	1.60
2-BUTANONE	ND<	7.85	ND<	4.28	ND<	1.60
1,1,1-TRICHLOROETHANE	ND<	7.85	ND<	4.28	ND<	1.60
CARBON TETRACHLORIDE	ND<	7.85	ND<	4.28	ND<	1.60
VINYL ACETATE	ND<	7.85	ND<	4.28	ND<	1.60
BROMODICHLOROMETHANE	ND<	7.85	ND<	4.28	ND<	1.60
1,2-DICHLOROPROPANE	ND<	7.85	ND<	4.28	ND<	1.60
CIS-1,3-DICHLOROPROPANE	ND<	7.85	ND<	4.28	ND<	1.60
TRICHLOROETHENE	ND<	7.85	ND<	4.28	ND<	1.60
DIBROMOCHLOROMETHANE	ND<	7.85	ND<	4.28	ND<	1.60
1,1,2-TRICHLOROETHANE	ND<	7.85	ND<	4.28	ND<	1.60
BENZENE		22.30		18.49		18.63
TRANS-1,3-DICHLOROPROPANE	ND<	7.85	ND<	4.28	ND<	1.60
2-CHLOROETHYLVINYLETHER	ND<	7.85	ND<	4.28	ND<	1.60
BROMOFORM	ND<	7.85	ND<	4.28	ND<	1.60
4-METHYL-2-PENTANONE	ND<	7.85	ND<	4.28	ND<	1.60
2-HEXANONE	ND<	7.85	ND<	4.28	ND<	1.60
TETRACHLOROETHENE	ND<	7.85	ND<	4.28	ND<	1.60
1,1,2,2-TETRACHLOROETHANE	ND<	7.85	ND<	4.28	ND<	1.60
TOLUENE		3.14 J		2.06 J		3.21
CHLOROBENZENE	ND<	7.85	ND<	4.28		1.22 J
ETHYLBENZENE	ND<	7.85	ND<	4.28	ND<	1.60
STYRENE	ND<	7.85	ND<	4.28	ND<	1.60
XYLENES (TOTAL)	ND<	7.85	ND<	4.28	ND<	1.60

TABLE 7.4-16. VOC IN VOST GAS SAMPLES FROM BAGHOUSE OUTLET (Location 19)-7/18/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N19VOS7181		N19VOS7182		N19VOS7183	
CHLOROMETHANE	ND	11.29	ND	5.41	ND	2.02
BROMOMETHANE	ND	11.29	ND	5.41	ND	2.02
VINYL CHLORIDE	ND	11.29	ND	5.41	ND	2.02
CHLOROETHANE	ND	11.29	ND	5.41	ND	2.02
METHYLENE CHLORIDE		1150.35		334.34	ND	2.02
ACETONE		48.82		205.76		4.36 J
CARBON DISULFIDE		5.87 J		4.73 J	ND	2.02
1,1-DICHLOROETHENE	ND	11.29	ND	5.41	ND	2.02
1,1-DICHLOROETHANE	ND	11.29	ND	5.41	ND	2.02
TRANS-1,2-DICHLOROETHENE	ND	11.29	ND	5.41	ND	2.02
CHLOROFORM	ND	11.29	ND	5.41	ND	2.02
1,2-DICHLOROETHANE	ND	11.29	ND	5.41	ND	2.02
2-BUTANONE	ND	11.29	ND	5.41	ND	2.02
1,1,1-TRICHLOROETHANE	ND	11.29	ND	5.41	ND	2.02
CARBON TETRACHLORIDE	ND	11.29	ND	5.41	ND	2.02
VINYL ACETATE	ND	11.29	ND	5.41	ND	2.02
BROMODICHLOROMETHANE	ND	11.29	ND	5.41	ND	2.02
1,2-DICHLOROPROPANE	ND	11.29	ND	5.41	ND	2.02
CIS-1,3-DICHLOROPROPANE	ND	11.29	ND	5.41	ND	2.02
TRICHLOROETHENE	ND	11.29	ND	5.41	ND	2.02
DIBROMOCHLOROMETHANE	ND	11.29	ND	5.41	ND	2.02
1,1,2-TRICHLOROETHANE	ND	11.29		6.24	ND	2.02
BENZENE		26.22		35.48		3.27 J
TRANS-1,3-DICHLOROPROPANE	ND	11.29	ND	5.41	ND	2.02
2-CHLOROETHYLVINYLETHER	ND	11.29	ND	5.41	ND	2.02
BROMOFORM	ND	11.29	ND	5.41	ND	2.02
4-METHYL-2-PENTANONE	ND	11.29		9.25	ND	2.02
2-HEXANONE		18.53		19.78	ND	2.02
TETRACHLOROETHENE	ND	11.29	ND	5.41	ND	2.02
1,1,2,2-TETRACHLOROETHANE	ND	11.29	ND	5.41	ND	2.02
TOLUENE		8.14 J		4.73 J	ND	2.02
CHLOROBENZENE	ND	11.29	ND	5.41	ND	2.02
ETHYLBENZENE	ND	11.29	ND	5.41	ND	2.02
STYRENE	ND	11.29	ND	5.41	ND	2.02
XYLENES (TOTAL)	ND	11.29	ND	5.41	ND	2.02

TABLE 7.4-21. VOC IN VOST GAS SAMPLES FROM SCR REACTOR OUTLET (Location 20) - 7/23/93 ($\mu\text{g}/\text{Nm}^3$)

Compound	N20VOS7231		N20VOS7232		N20VOS7233	
CHLOROMETHANE	ND<	12.46	ND<	6.61	ND<	2.31
BROMOMETHANE		209.56	ND<	6.61	ND<	2.31
VINYL CHLORIDE	ND<	12.46	ND<	6.61	ND<	2.31
CHLOROETHANE	ND<	12.46	ND<	6.61	ND<	2.31
METHYLENE CHLORIDE		42.41		35.15		9.52
ACETONE	ND<	12.46		28.28		12.84
CARBON DISULFIDE		10.48 J		10.57		3.70
1,1-DICHLOROETHENE	ND<	12.46	ND<	6.61	ND<	2.31
1,1-DICHLOROETHANE	ND<	12.46	ND<	6.61	ND<	2.31
TRANS-1,2-DICHLOROETHENE	ND<	12.46	ND<	6.61	ND<	2.31
CHLOROFORM	ND<	12.46	ND<	6.61	ND<	2.31
1,2-DICHLOROETHANE	ND<	12.46	ND<	6.61	ND<	2.31
2-BUTANONE	ND<	12.46	ND<	6.61	ND<	2.31
1,1,1-TRICHLOROETHANE	ND<	12.46	ND<	6.61	ND<	2.31
CARBON TETRACHLORIDE	ND<	12.46	ND<	6.61	ND<	2.31
VINYL ACETATE	ND<	12.46	ND<	6.61	ND<	2.31
BROMODICHLOROMETHANE	ND<	12.46	ND<	6.61	ND<	2.31
1,2-DICHLOROPROPANE	ND<	12.46	ND<	6.61	ND<	2.31
CIS-1,3-DICHLOROPROPANE	ND<	12.46	ND<	6.61	ND<	2.31
TRICHLOROETHENE	ND<	12.46	ND<	6.61	ND<	2.31
DIBROMOCHLOROMETHANE	ND<	12.46	ND<	6.61	ND<	2.31
1,1,2-TRICHLOROETHANE	ND<	12.46	ND<	6.61	ND<	2.31
BENZENE	ND<	12.46		3.44 J		2.03 J
TRANS-1,3-DICHLOROPROPANE	ND<	12.46	ND<	6.61	ND<	2.31
2-CHLOROETHYLVINYLETHER	ND<	12.46	ND<	6.61	ND<	2.31
BROMOFORM	ND<	12.46	ND<	6.61	ND<	2.31
4-METHYL-2-PENTANONE	ND<	12.46	ND<	6.61	ND<	2.31
2-HEXANONE		66.36	ND<	6.61	ND<	2.31
TETRACHLOROETHENE	ND<	12.46	ND<	6.61	ND<	2.31
1,1,2,2-TETRACHLOROETHANE	ND<	12.46	ND<	6.61	ND<	2.31
TOLUENE		19.46		9.78		6.19
CHLOROBENZENE	ND<	12.46	ND<	6.61	ND<	2.31
ETHYLBENZENE	ND<	12.46	ND<	6.61	ND<	2.31
STYRENE	ND<	12.46	ND<	6.61	ND<	2.31
XYLENES (TOTAL)	ND<	12.46	ND<	6.61	ND<	2.31

TABLE 7.4-22. VOC IN VOST GAS SAMPLES FROM WSA TOWER OUTLET (Location 21)-7/18/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N21VOS7181		N21VOS7182		N21VOS7183
CHLOROMETHANE	ND<	15.59		1085.95		682.47
BROMOMETHANE	ND<	15.59	ND<	3.55		6.09
VINYL CHLORIDE	ND<	15.59	ND<	3.55	ND<	2.58
CHLOROETHANE	ND<	15.59	ND<	3.55	ND<	2.58
METHYLENE CHLORIDE		100.28		17.77		14.24
ACETONE		154.46		36.68		23.01
CARBON DISULFIDE	ND<	15.59		2.84 J		2.06 J
1,1-DICHLOROETHENE	ND<	15.59	ND<	3.55	ND<	2.58
1,1-DICHLOROETHANE	ND<	15.59	ND<	3.55	ND<	2.58
TRANS-1,2-DICHLOROETHENE	ND<	15.59	ND<	3.55	ND<	2.58
CHLOROFORM	ND<	15.59	ND<	3.55	ND<	2.58
1,2-DICHLOROETHANE	ND<	15.59	ND<	3.55	ND<	2.58
2-BUTANONE	ND<	15.59	ND<	3.55	ND<	2.58
1,1,1-TRICHLOROETHANE	ND<	15.59	ND<	3.55	ND<	2.58
CARBON TETRACHLORIDE	ND<	15.59	ND<	3.55	ND<	2.58
VINYL ACETATE	ND<	15.59	ND<	3.55	ND<	2.58
BROMODICHLOROMETHANE	ND<	15.59	ND<	3.55	ND<	2.58
1,2-DICHLOROPROPANE	ND<	15.59	ND<	3.55	ND<	2.58
CIS-1,3-DICHLOROPROPANE	ND<	15.59	ND<	3.55	ND<	2.58
TRICHLOROETHENE	ND<	15.59	ND<	3.55	ND<	2.58
DIBROMOCHLOROMETHANE	ND<	15.59	ND<	3.55	ND<	2.58
1,1,2-TRICHLOROETHANE	ND<	15.59	ND<	3.55	ND<	2.58
BENZENE		8.72 J		2.99 J		3.20
TRANS-1,3-DICHLOROPROPANE	ND<	15.59	ND<	3.55	ND<	2.58
2-CHLOROETHYL VINYLETHER	ND<	15.59	ND<	3.55	ND<	2.58
BROMOFORM	ND<	15.59	ND<	3.55	ND<	2.58
4-METHYL-2-PENTANONE	ND<	15.59	ND<	3.55	ND<	2.58
2-HEXANONE	ND<	15.59	ND<	3.55		38.90
TETRACHLOROETHENE	ND<	15.59	ND<	3.55	ND<	2.58
1,1,2,2-TETRACHLOROETHANE	ND<	15.59	ND<	3.55	ND<	2.58
TOLUENE		18.06		3.84		4.33
CHLOROBENZENE	ND<	15.59	ND<	3.55	ND<	2.58
ETHYLBENZENE	ND<	15.59	ND<	3.55	ND<	2.58
STYRENE	ND<	15.59	ND<	3.55	ND<	2.58
XYLENES (TOTAL)	ND<	15.59	ND<	3.55	ND<	2.58

TABLE 7.4-23. VOC IN VOST GAS SAMPLES FROM WSA TOWER OUTLET (Location 21)-7/21/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N21VOS7211		N21VOS7212		N21VOS7213
CHLOROMETHANE		294.90		237.07		81.02
BROMOMETHANE		34.55		18.24	ND<	2.41
VINYL CHLORIDE	ND<	20.09	ND<	8.00	ND<	2.41
CHLOROETHANE	ND<	20.09	ND<	8.00	ND<	2.41
METHYLENE CHLORIDE		26.52		5.12 J	ND<	2.41
ACETONE		188.83		50.87		24.50
CARBON DISULFIDE	ND<	20.09	ND<	8.00		0.96 J
1,1-DICHLOROETHENE	ND<	20.09	ND<	8.00	ND<	2.41
1,1-DICHLOROETHANE	ND<	20.09	ND<	8.00	ND<	2.41
TRANS-1,2-DICHLOROETHENE	ND<	20.09	ND<	8.00	ND<	2.41
CHLOROFORM	ND<	20.09	ND<	8.00	ND<	2.41
1,2-DICHLOROETHANE	ND<	20.09	ND<	8.00	ND<	2.41
2-BUTANONE	ND<	20.09	ND<	8.00		2.22 J
1,1,1-TRICHLOROETHANE	ND<	20.09	ND<	8.00	ND<	2.41
CARBON TETRACHLORIDE	ND<	20.09	ND<	8.00	ND<	2.41
VINYL ACETATE	ND<	20.09	ND<	8.00	ND<	2.41
BROMODICHLOROMETHANE	ND<	20.09	ND<	8.00	ND<	2.41
1,2-DICHLOROPROPANE	ND<	20.09	ND<	8.00	ND<	2.41
CIS-1,3-DICHLOROPROPANE	ND<	20.09	ND<	8.00	ND<	2.41
TRICHLOROETHENE	ND<	20.09	ND<	8.00	ND<	2.41
DIBROMOCHLOROMETHANE	ND<	20.09	ND<	8.00	ND<	2.41
1,1,2-TRICHLOROETHANE		33.75		4.80 J	ND<	2.41
BENZENE		12.05 J		7.04 J		5.50
TRANS-1,3-DICHLOROPROPANE	ND<	20.09	ND<	8.00	ND<	2.41
2-CHLOROETHYL VINYLETHER	ND<	20.09	ND<	8.00	ND<	2.41
BROMOFORM	ND<	20.09	ND<	8.00	ND<	2.41
4-METHYL-2-PENTANONE	ND<	20.09	ND<	8.00	ND<	2.41
2-HEXANONE		166.33	ND<	8.00	ND<	2.41
TETRACHLOROETHENE	ND<	20.09	ND<	8.00	ND<	2.41
1,1,2,2-TETRACHLOROETHANE	ND<	20.09	ND<	8.00	ND<	2.41
TOLUENE		12.05 J	ND<	8.00		3.18
CHLOROBENZENE	ND<	20.09	ND<	8.00	ND<	2.41
ETHYLBENZENE	ND<	20.09	ND<	8.00	ND<	2.41
STYRENE	ND<	20.09	ND<	8.00	ND<	2.41
XYLENES (TOTAL)	ND<	20.09	ND<	8.00	ND<	2.41

TABLE 7.4-24. VOC IN VOST GAS SAMPLES FROM WSA TOWER OUTLET (Location 21) - 7/23/93 ($\mu\text{g}/\text{Nm}^3$)

Compound		N21VOS7231	N21VOS7232	N21VOS7233
CHLOROMETHANE		244.67	ND	5.52
BROMOMETHANE		31.08	ND	5.52
VINYL CHLORIDE	ND	12.55	ND	5.52
CHLOROETHANE		12.53	ND	5.52
METHYLENE CHLORIDE		128.35		10.80
ACETONE		48.63		17.64
CARBON DISULFIDE		8.02 J		3.31 J
1,1-DICHLOROETHENE	ND	12.55	ND	5.52
1,1-DICHLOROETHANE	ND	12.55	ND	5.52
TRANS-1,2-DICHLOROETHENE	ND	12.55	ND	5.52
CHLOROFORM	ND	12.55	ND	5.52
1,2-DICHLOROETHANE	ND	12.55	ND	5.52
2-BUTANONE	ND	12.55	ND	5.52
1,1,1-TRICHLOROETHANE	ND	12.55	ND	5.52
CARBON TETRACHLORIDE	ND	12.55	ND	5.52
VINYL ACETATE	ND	12.55	ND	5.52
BROMODICHLOROMETHANE	ND	12.55	ND	5.52
1,2-DICHLOROPROPANE	ND	12.55	ND	5.52
CIS-1,3-DICHLOROPROPANE	ND	12.55	ND	5.52
TRICHLOROETHENE	ND	12.55	ND	5.52
DIBROMOCHLOROMETHANE	ND	12.55	ND	5.52
1,1,2-TRICHLOROETHANE	ND	12.55	ND	5.52
BENZENE		15.54		10.36
TRANS-1,3-DICHLOROPROPANE	ND	12.55	ND	5.52
2-CHLOROETHYLVINYLETHER	ND	12.55	ND	5.52
BROMOFORM	ND	12.55	ND	5.52
4-METHYL-2-PENTANONE	ND	12.55	ND	5.52
2-HEXANONE	ND	12.55	ND	5.52
TETRACHLOROETHENE	ND	12.55	ND	5.52
1,1,2,2-TETRACHLOROETHANE	ND	12.55	ND	5.52
TOLUENE		5.51 J		2.43 J
CHLOROBENZENE	ND	12.55	ND	5.52
ETHYLBENZENE	ND	12.55	ND	5.52
STYRENE	ND	12.55	ND	5.52
XYLENES (TOTAL)	ND	12.55	ND	5.52

TABLE 7.4-25. COMPARISON OF CAN AND VOST RESULTS FOR SELECT COMPOUNDS ($\mu\text{g}/\text{Nm}^3$)

TestRun I.D.	Dichloromethane		Benzene		Toluene	
	CAN	VOST	CAN	VOST	CAN	VOST
N-18-718-1	155.95	70.30	6.51	22.32	ND<	2.37
N-18-718-2	78.81	25.81	6.51	17.65	ND<	2.37
N-18-718-3	42.55	7.841	7.87	13.81	ND<	2.37
N-18-721-1	113.31	33.26	8.12	65.01	ND<	2.44
N-18-721-2	14.47	9.458	9.28	100.8	ND<	2.44
N-18-721-3	18.49	ND<	13.28	ND<	ND<	2.44
N-18-723-1	886.38 E	28.75	7.43	22.68	ND<	2.22
N-18-723-2	239.76	15.67	10.74	18.80	ND<	2.22
N-18-723-3	139.61	7.160	10.54	18.94	ND<	2.22
N-19-718-1	544.69	1169.	29.13	26.66	ND<	2.49
N-19-718-2	368.11	340.0	30.67	36.08	ND<	2.49
N-19-718-3	117.65	ND<	15.54	3.325 J	ND<	2.49
N-19-721-1	96.63	23.28	9.35	10.16 J	ND<	2.41
N-19-721-2	8.92	64.65	8.80	11.13	ND<	2.41
N-19-721-3	8.52	2.237	10.79	6.671	ND<	2.41
N-19-723-1	99.95	301.9	8.09	45.69	ND<	2.37
N-19-723-2	18.63	107.0	10.15	36.84	ND<	2.37
N-19-723-3	10.04	12.61	7.58	26.26	ND<	2.37
N-20-718-1	396.72	218.8	40.95	10.47 J	ND<	15.43
N-20-718-2	3.86	6.956	ND<	6.00	ND<	2.70
N-20-718-3	31.57	3.376	7.35	1.515 J	ND<	3.17
N-20-721-1	505.40	53.60	3.77	26.99	ND<	2.79
N-20-721-2	374.75	6.95 J	ND<	4.627 J	ND<	2.79
N-20-721-3	267.06	1.505 J	ND<	3.010	ND<	2.79
N-20-723-1	251.79	43.13	ND<	ND<	ND<	2.89
N-20-723-2	115.82	35.74	ND<	3.496 J	ND<	2.89
N-20-723-3	178.22	9.682	ND<	2.064 J	ND<	2.89
N-21-718-1	314.61	101.9	2.31	8.868 J	ND<	2.52
N-21-718-2	220.78	18.07	ND<	3.041 J	ND<	2.52
N-21-718-3	180.47	14.48	ND<	3.254	ND<	2.52
N-21-721-1	1932.2 E	26.97	74.20	12.25 J	ND<	19.27
N-21-721-2	1205.2 E	5.207 J	38.54	7.160 J	ND<	2.89
N-21-721-3	1635.6 E	ND<	127.57	5.593	990.8 E	3.234
N-21-723-1	3829.5 E	130.5	4.79	15.80	700.5 E	5.604 J
N-21-723-2	3817.0 E	10.98	ND<	10.53	835.5 E	2.471 J
N-21-723-3	3997.6 E	18.99	ND<	3.752	778.8 E	2.532

ND< indicates that the compound was not detected.

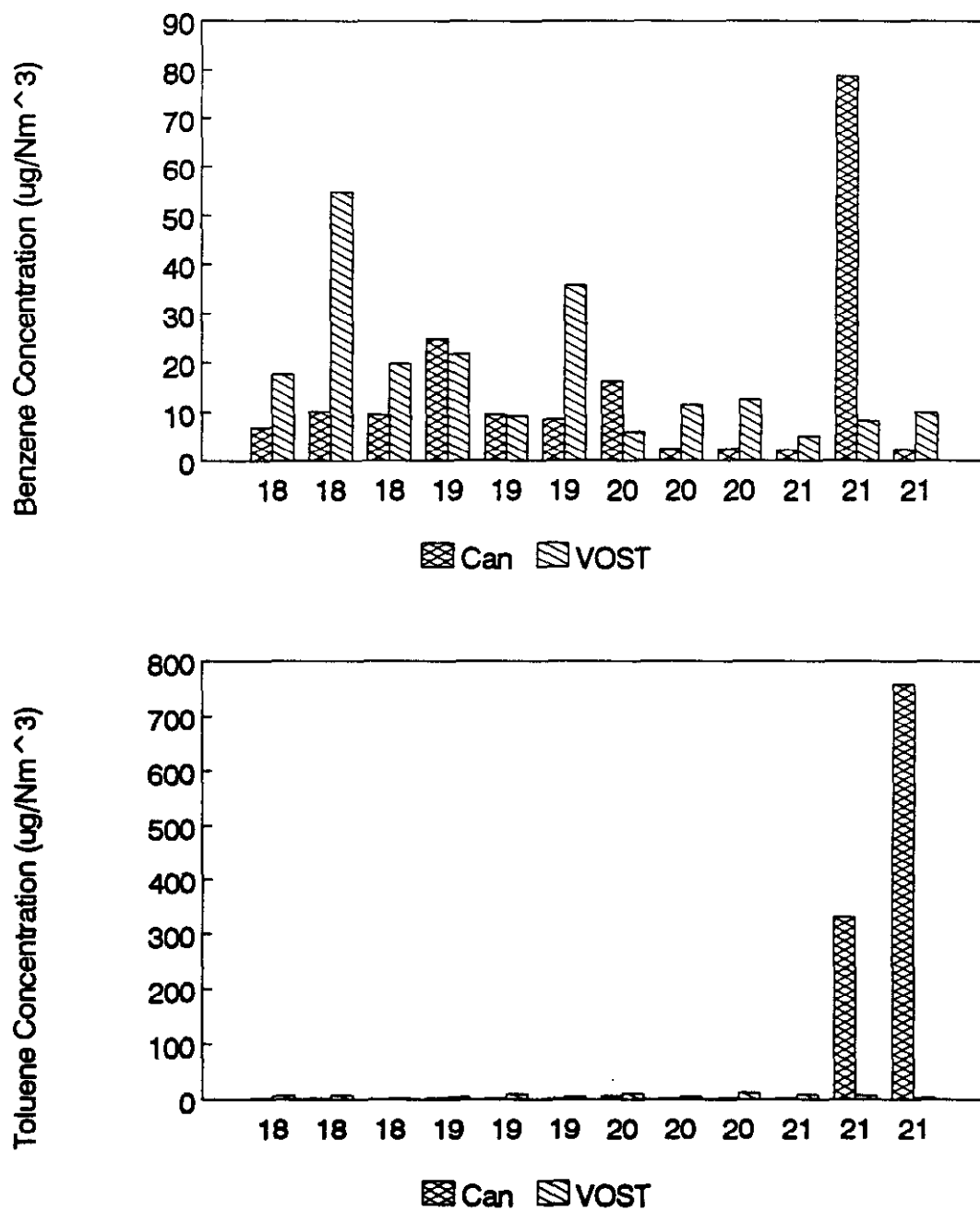


Figure 7.4-1. Can versus VOST comparison for benzene and toluene daily averages

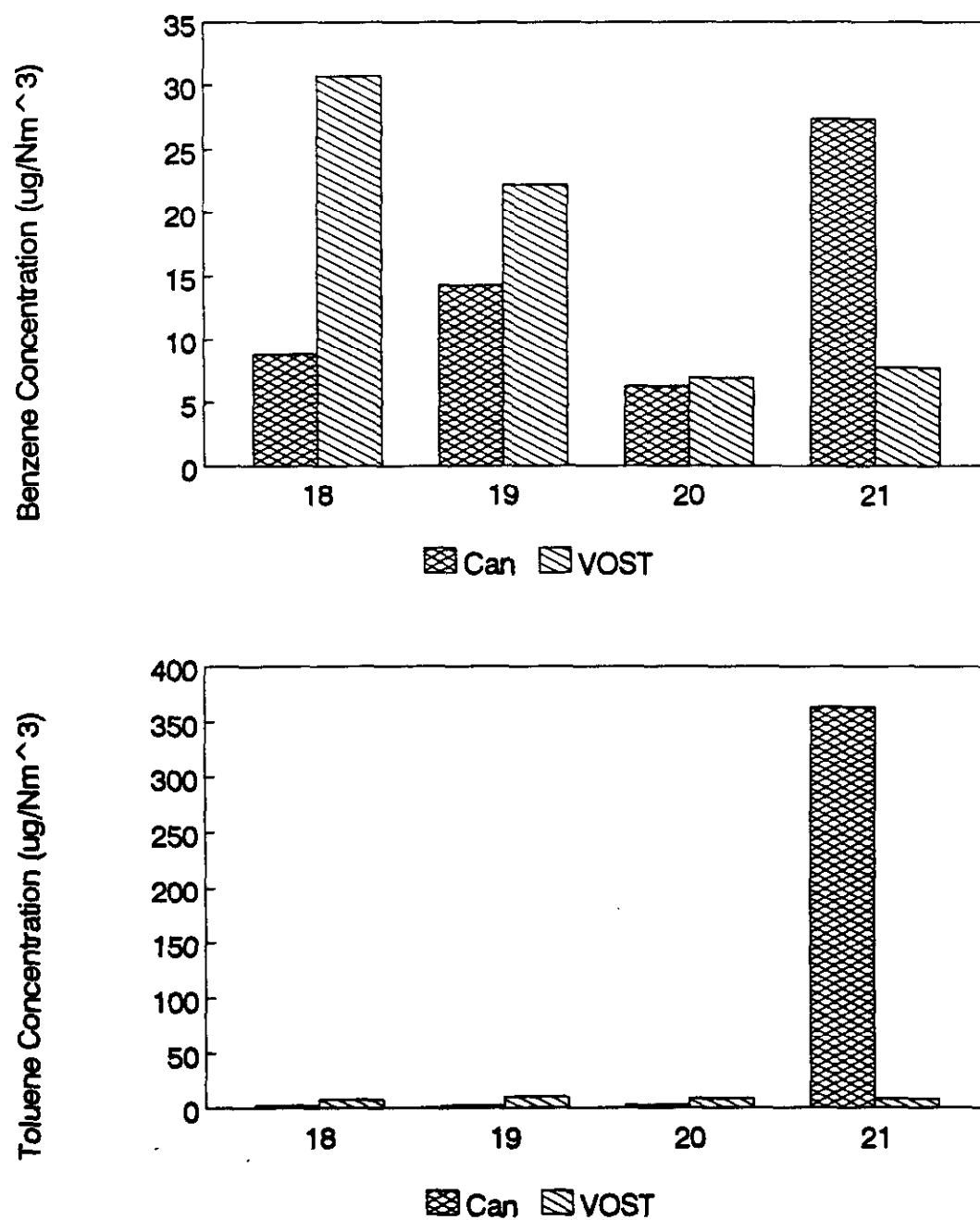


Figure 7.4-2. Can versus VOST comparison for benzene and toluene location averages

7.5 Mercury Results for Individual Method 29 Components

The individual components of the Method 29 (M29) train were analyzed separately for mercury at the request of DOE, rather than combining front-half and back-half components as is standard practice in Method 29 procedures. The results for these individual component analyses are presented in Table 7.5-1, for each of the three inorganic sampling days at the baghouse inlet (Location 18), baghouse outlet (Location 19), SCR unit outlet (Location 20), and the WSA condenser outlet (Location 21).

The results in Table 7.5-1 show that at both locations the great majority of mercury was found in the impinger components of the M29 train. In all cases, most of the mercury (54 to 90 percent, averaging 76 percent) was captured in the H₂O₂ impingers; the KMnO₄ impingers (which are located downstream of the H₂O₂ impingers in the Method 29 train) captured a smaller fraction of the mercury (8 to 35) percent, averaging 21 percent).

TABLE 7.5-1. RESULTS FOR MERCURY IN GAS SAMPLES FROM NILES-SNOX

Sample Component	BAGHOUSE INLET						BAGHOUSE OUTLET						SCR UNIT OUTLET						WSA CONDENSER OUTLET					
	N-18-MUM-719	N-18-MUM-722	N-18-MUM-724	N-18-MUM-719	N-18-MUM-722	N-18-MUM-724	N-18-MUM-719	N-18-MUM-722	N-18-MUM-724	N-18-MUM-719	N-18-MUM-722	N-18-MUM-724	N-20-MUM-719	N-20-MUM-722	N-20-MUM-724	N-20-MUM-719	N-20-MUM-722	N-20-MUM-724	N-21-MUM-719	N-21-MUM-722	N-21-MUM-724	N-21-MUM-719	N-21-MUM-722	N-21-MUM-724
	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total	ug/ Nm ³	% of Total
KMNO4 Impinger	8.6	26%	5.3	20%	4.9	23%	3.9	14%	3.6	14%	2.9	10%	2.7	8%	5.5	19%	4.4	16%	11.3	31%	7.0	32%	10.6	35%
H2O2 Impinger	23.6	68%	20.1	76%	15.0	70%	24.4	86%	22.3	86%	26.7	80%	31.3	87%	23.5	81%	23.1	84%	24.1	67%	14.2	65%	18.5	54%
Acid Probe Rinse	1.3	4%	0.61	3%	1.2	6%	0.05	0.2%	0	0%	0	0%	0.53	1%	0.02	0.1%	0	0%	0	0%	0.12	1%	0.10	0.3%
Acetone Probe Rinse	0	0%	0.10	0.4%	0	0%	0	0%	0	0%	0	0%	1.3	4%	0	0%	0.06	0.2%	0.79	2%	0.70	3%	3.3	11%
Filter	0	0%	0.27	1%	0.41	2%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0.06	0.2%	0	0%	0	0%
Large Cyclones	0.90	3%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Small Cyclones	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Total	34.6		26.6		21.6		28.4		25.8		28.6		35.9		29.0		27.6		36.3		22.0		30.5	